DO HANDS DO ALL YOUR THINKING?

AN EXPERIMENTAL STUDY OF ‘MANIPULATION-SPECIFICITY’

By

GABRIELE PASCHEK, M. A.

A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in the Department of Psycholinguistics at the

UNIVERSITY OF BIELEFELD
FACULTY OF LINGUISTICS AND LITERARY STUDIES

Supervisor: Prof. Dr. Jan de Ruiter
Co-Supervisor: Dr. Lorenz Sichelschmidt

April 2014

Für meine Mutter.
Weil Du mir gezeigt hast, wie kostbar Wissen ist.
Weil Du mir mit Deinem Kampfgeist das größte Vorbild bist.
Weil Du immer an mich glaubst.

Acknowledgments

So many people have contributed to the success of my dissertation. First and foremost, I would like to express my gratitude to my supervisor, Jan de Ruiter, who taught me that science has to be fun. That is exactly, what my dissertation was – most of the time. And this was made possible by Jan, his support and his unusual way of thinking, which convinced me to take the road less travelled by. The best example for this, was the very special and very entertaining car drive to Düsseldorf Airport, which I will never forget. Apropos by nothing, a great conversation turned into a firework of extraordinary ideas and resulted in laying the foundation stone of the most central thesis of my dissertation.

The foundation stone of my statistical knowledge was laid by Max Sichelschmidt, when I was a young student in my first semesters in Bielefeld. Thus, being supported by him as co-supervisor now, gave me the necessary confidence and confirmation, while juggling with all these figures. That is why I want to give my sincere thanks to him.

Furthermore, I wish to thank Sebastian Loth, who helped with words and deeds so many times. Especially, his programming skills saved me from going crazy, while designing my first computer-based experiment. I also would like to thank Chris Cummins for his detailed proofreading. His special feeling for the English language was such a great help when I was desperately searching for the right words to express my thoughts.

Finally, I want to thank my partner and best friend Markus for his support and his age-long patience. Years over years, he braved all my monologues about embodiment, understood without a word that I had far too little time and suffered with me, when I looked desperately for left-handers – for months.

Abstract

People are equipped with an additional ‘mental pair of hands’ that has a strong impact on how they act, but not on the decisions that they make. This is the conclusion drawn by this thesis. Two experiments discover the limitations of the body specificity hypothesis (Casasanto, 2009) by revealing that the impact of handedness is only relevant in *active placement tasks* and not in *perceptual judgment tasks.* Hence, people seem to act the way they do only for reasons of comfort. Whereas people place superior objects in a way that guarantees optimal accessibility, they do not consider the placements themselves to constitute positive or negative attributes of the object. This is further manifest in an extended replication of the Shepard task (Shepard & Metzler, 1971), which tests the ability to rotate virtual objects mentally. This task revealed that people prefer to virtually move the objects that are placed on the preferred side of their body. This finding also fits the results from the first two experiments. Taking into account the findings from all three experiments, a modified account of embodiment suggests itself. For this reason a *manipulation-specificity hypothesis* is articulated, which at once points to the link between real and mental manipulation of objects and explains the economy with which people solve active placement as well as mental simulation tasks. Thus, mental acting indeed seems to be embodied, but judging does not.

Zusammenfassung

Menschen sind mit einem zusätzlichen „mentalen Händepaar" ausgestattet. Es hat einen starken Einfluss auf das Handeln – nicht aber auf Entscheidungen. Dies ist die Schlussfolgerung, welche aus dieser Arbeit gezogen werden kann. Zwei Experimente decken die Grenzen der *body specificity hypothesis* (Casasanto, 2009) auf, indem sie zeigen, dass Händigkeit nur auf das aktive Platzieren einen Einfluss hat, perzeptive Urteile hingegen davon unbeeinflusst bleiben. Folglich scheinen Menschen das, was sie tun, nur aus Gründen der Bequemlichkeit zu tun. Menschen neigen dazu, bessere Objekte so zu platzieren, dass ihre optimale Erreichbarkeit garantiert werden kann. Platzierungen selbst werden nicht als positive oder negative Attribute der Objekte wahrgenommen. Dies ist mit einer erweiterten Replikation des Shepard-Experiments (Shepard & Metzler, 1971) untermauert, welche die Fähigkeit testet, virtuelle Objekte geistig zu drehen. Dieses Experiment hat gezeigt, dass Menschen es vorziehen, diejenigen Objekte virtuell zu bewegen, die auf der bevorzugten Seite ihres Körpers platziert werden. Damit entspricht das Ergebnis auch den Resultaten der ersten beiden Experimente. Die gebündelte Betrachtung der Erkenntnisse aller drei Experimente legt sogar eine modifizierte Darstellung des *Embodiment* nahe. Aus diesem Grund wird eine *manipulation-specificity hypothesis* formuliert, welche auf die Verbindung zwischen der realen und mentalen Manipulation von Objekten verweist und zugleich das ökonomische Verhalten erklärt, mit denen Menschen Aufgaben lösen, die aktives Platzieren sowie mentales Simulieren erfordern. Dieser Hypothese nach ist mentales Agieren in der Tat *embodied* – das Urteilen hingegen nicht.

Table of Contents

1. Introduction

Embodiment – this word has been a game changer for cognitive science, since it appeared in the 1990s. After centuries throughout which the human mind was considered to be an isolated computing center that operated far from the influences of the body, more and more experiments provided evidence that it is rather the form of the human body that largely determines the nature of the human mind (e.g. Barsalou, 1999; Goldstone & Barsalou, 1998; Lakoff & Johnson, 1999). But is this influence really as strong as the proponents of embodiment have suggested? Critics have complained about the overblown conclusions drawn from the results of embodiment studies. For instance, Adam (2010) pointed out that studies showing significant effects could also be interpreted in terms of priming or facilitative movements. However, researchers investigating embodiment have almost always interpreted their results as evidence in favour of embodied cognition. This thesis aims at testing whether the critical prediction holds that the body determines the mind, or whether other interpretations are possible and even more plausible.

Specifically, I present three experiments which test whether the ability to perform mental simulations is determined by being left- or right-handed. Handedness is defined as a preference for performing certain tasks with different sides of the body, for example holding a pen in the left or the right hand. If the body determines the mind as strongly as the proponents of embodiment have suggested, people with different body-related preferences such as handedness should think in a different way. Thus, studying the effects of handedness might reveal interesting aspects of embodiment. Indeed, there is neuroscientific evidence indicating that processes related to tasks such as writing recruit different hemispheres of the brain in left- and right-handers (Holder, 1997). However, this distinction could also be attributed to individuals having more training in computing precise movement with one hemisphere than with another, resulting in a preference depending upon handedness. This interplay between cerebral activities, frequency and handedness could offer a valid explanation for why one side of the body is typically able to perform certain fine motor tasks more precisely and faster.

The psychologist Daniel Casasanto (2009) conducted a series of experiments on the differences between right- and left-handers and interpreted the results as supporting the body-specificity hypothesis. This hypothesis is based on the assumption that people with different bodies create different mental representations of reality. These differences are suspected to significantly influence the way people form a decision at every single moment of their lives. Casasanto (2009) claims, for instance, that right-handed people should be influenced by having had frustrating experiences connected with the use of their less able left hands, and consequently develop negative associations with that side (such that, abstractly, ‘right is good’ and ‘left is bad’). However, data supporting this claim was only elicited from the right-handers tested. The data of left-handers did not show signs of the corresponding preference structure (‘right is bad’ and ‘left is good’).

In summary, these results are clearly important to the validity of the embodiment hypothesis, but the experimental support is less than conclusive. To address this shortcoming, I decided to attempt to replicate one of Casasanto’s (2009) experiments. This experiment, which I report in this thesis, focuses on the influence of handedness in perceptual judgment tasks. I will use the results of this task to motivate two further experiments – the first involving active placement, the second a variation of Shepard and Metzler’s (1971) study investigating the perception and processing of drawings. Taken together, the experiments provide evidence both from perception and production tasks, and consequently offer more comprehensive and conclusive findings than prior studies. This permits a better evaluation of the body specificity hypothesis and other accounts of embodiment (e.g. Wilson, 2002).

In this thesis, I start by explaining the embodiment theory and the potential influence of the body on the development of abstract concepts in Chapter 1.1. The body-specificity hypothesis (Casasanto, 2009), which extends the embodiment theory, is outlined in Chapter 1.2. After presenting a general view of the current research in Chapter 1.2.3, a perceptual judgment task of Casasanto (2009) – the so-called Shopping Tour – is evaluated in Chapter 2. In this Chapter I reanalyse and reinterpret this experiment with regards to the question of whether a body-specific effect occurs in both groups – the right-handers and the left-handers. In Chapter 3 I present an experiment for testing perceptual judgment. This experiment is a modified version of the Shopping Tour experiment of Casasanto (2009) and is analysed within the framework of this dissertation. The results are compared to the original experiment (Casasanto 2009). Additionally, in Chapter 4 I test the influence of handedness on active placement. Neither experiment supports the body-specificity hypothesis.

The body-specificity hypothesis claims that mental and physical differences also affect mental tasks, which are not linked to values such as “good” and “bad”. One well-known example is the Shepard Task (Shepard & Metzler, 1971). In Chapter 6, I review replications which are related to embodiment and discuss Wilson’s (2002) claims about offline cognition. Experiment 3 tests spatial computations. I conclude by presenting a modified account of embodiment that takes into account the findings from all three experiments. The account explicates how the body influences the cognitive processes in manipulation tasks, and for this reason I refer to it as the manipulation-specificity hypothesis.

1.1 How do mental metaphors emerge?

At least since de Saussure (1916), arbitrariness has been identified as an important characteristic of language. One and the same object is named differently in different languages. A connection between the meaning of words and their form or sound is not recognizable in the majority of cases.

> Arbitrariness does not mean that the individual speaker can proceed quite freely in the choice of linguistic constructions: from the standpoint of language acquisition and communication, the speaker experiences

> the connection between sign and meaning as customary and obligatory. (Bussmann, 1996, p. 32).

Consequently, arbitrariness is established as a universal characteristic of language. The comparison of different languages makes this particularly clear. "It's generally impossible to guess the meaning of an unfamiliar word, and each new word just has to be learned individually." (Trask, 1999). Much evidence suggests that the meanings of words are not generally predicted by the letters that they happen to contain. Consequently, the production of particular speech sounds does not necessarily convey especial meanings. It may be due instead to the “principle of least effort” (Zipf, 1949; Martinet 1955). The assimilation of /n/ to /m/ in a word such as “input” does not reflect a change of meaning but merely articulatory convenience. Similarly, on this account, falling intonation at the end of sentences is reflective merely of the lower air pressure available to the speaker at this stage of the utterance, rather than any conscious decision to mark declarative sentences in this way. Any alternative realisation would simply require more effort.

Since arbitrariness and the “principle of least effort” serve as valid explanations for many characteristics of language, these concepts might also be applicable to the development of linguistic metaphors such as “he reached the summit of his career” and familiar phrases that connect spatial expressions with abstract concepts in such a way as to associate the “top” with positive qualities and the “bottom” with negative qualities (*be on top*, *hit rock bottom*, and so on). Linguistic metaphors facilitate the expression of complex issues, if the metaphors are easy to memorize. In the case of spatial metaphors, there are several factors that reinforce this connection. Even elementary mathematics serves as a mnemonic for these concepts. In a coordinate system *top* is linked with *more*, which in turn tends to be associated with positive attributes (having *more* food, *more* time or *more* money is good). The permanent confrontation with these arbitrarily developed linguistic metaphors could have led to the emergence of mental metaphors. That means, in effect, that speakers would have been simply conditioned by language in establishing a link between *top* and *good* and between *bottom* and *bad*. If so, a person’s body and their physical experiences would not be responsible for the emergence of the corresponding spatial metaphors.

In contrast to this, the *body-specificity hypothesis* (Casasanto, 2009) claims that physical properties influence the development of linguistic metaphors. This hypothesis is rooted in embodiment – the idea that the experiences of a person's body, and the mental representations of those experiences, are able to exert influence on the way the person thinks and acts. Hence, before introducing the body-specificity hypothesis in more detail and continuing the discussion about the emergence of linguistic metaphors, I will provide a short overview of the research findings concerning embodiment.

Compared to the classical point of view in cognitive psychology, embodiment seems to change everything. For centuries, classical cognitive psychologists used to posit the mind as the origin of abstract information. The body was not perceived as the main determiner (e.g. Chomsky, 1968). This claim originated more than three centuries earlier. Descartes (1641) formulated the doctrine of Cartesian Dualism, which states that the mind is nonphysical and the container of consciousness, self-awareness and, hence, cognition. In contrast to the brain, which was seen by Descartes as the seat of intelligence, the mind was strictly separated from physical or environmental influences. In more detail, Cartesianism asserts the existence of a mode of cognition which is not influenced by the characteristics and experiences of the human body.

The proponents of embodiment highlight the relationship between environment, experience and cognition. With this rationale, embodiment succeeds in showing that mental representations are closely linked with those sensorimotor systems that experience represented objects (Barsalou 1999; Beilock & Holt 2007). A large number of experiments have provided evidence in support of these theories. For instance, Riskind & Gotay (1982) analysed the effect of posture on motivation and emotion. Participants sitting in a bent position significantly more often exhibited a state of mind described as *learned helplessness*. An experiment conducted by Strack, Martin &

Stepper (1988) verified the so-called Facial Feedback Hypothesis, originated by Darwin in 1872.

> The free expression by outward signs of an emotion intensifies it. On the other hand, the repression, as far as this is possible, of all outward signs softens our emotions... Even the simulation of an emotion tends to arouse it in our minds." (Darwin, 1872, p. 366)

Strack, Martin & Stepper (1988) tested this claim by telling the participants they wanted to investigate the difficulty of performing certain tasks when people are not able to use their hands and arms. The participants were asked to hold a pen in their mouth in one of two ways: in a *lips* condition, activating the orbicularis oris muscle and leading to a frown, as well as in a *teeth* condition activating zygomaticus major and leading to a smile. In one of the tasks the participants had to rate how funny a cartoon was. The participants in the teeth condition gave significantly higher ratings than the participants in the lips condition or the control group. The unintentional smile put the subjects in a more cheerful mood, as predicted by Darwin's (1872) theory.

In another experiment (Tettamanti et al., 2005), participants were asked to read out loud words such as 'run' or 'kick', which could be associated with the movement of arms or legs. The results showed that the perception of these words activated the same cerebral areas that are involved while moving the corresponding extremities, and thus cohered with the embodiment view. Zhong & Liljenquist (2006) went one step further in detecting the "Macbeth Effect". Participants remembering and talking about an immoral situation linked physical cleansing with an act of washing away their sins. Hence, the concepts of moral and physical cleanliness seem to be closely linked. But is the "Macbeth Effect" a result of physical experiences or merely learned from the culture that a person lives in?

This controversy leads us back to the issues discussed earlier about the development of mental representation and, furthermore, the body as the origin of linguistic metaphors. Undeniably, mental representations are not merely products of our mind. A person’s body and the sensorimotor experiences that the person makes with this body are highly involved in the creation of mental representations. Some proponents of embodiment even go one step further, and promote the shape and the abilities of the human body as being mainly responsible for our way of thinking. That would imply that all areas of cognition – categories, concepts, information and ideas – as well as language and linguistic structures are products of the body’s experiences and perception.

Casasanto (2009) argues that it is the body that determines the shape of abstract concepts such as *good* and *bad*. The fact that we use the concepts *top is good* and *bottom is bad* in our everyday life, seems to support this approach (Schubert, 2005). The literal meaning of *top* and *bottom* is established on the basis of spatial orientation. Nevertheless, speakers of many languages also use these terms with an evaluative meaning. Thus, *top* and *bottom* can also be used in order to characterize issues, objects or persons as *good* or *bad*. For instance, the phrase *high on life* is used for a happy person, whereas *low IQ* would describe someone who is not very intelligent. Other idioms which include these spatial concepts can often be found in subtle areas of the English language. The phrases *spirits soar* and *hopes plummet*, for instance, visualize movements that cannot be observed, since these movements have only a metaphorical or abstract meaning (Gibbs 1994; Lakoff & Johnson 1999). This metaphorical use can also be applied to hierarchical structures.

> When someone has a *high* status, or is *up* in the hierarchy, he or she has control *over* and can *over*see others who have *lower* status. One can look *up* to those who *rose* to the *height* of their power or look *down* on *under*lings. (Schubert 2005, p. 1)

These spatial terms can be found in many languages, when – for example – hierarchical structures in society or power relations are described. Words that contain the concept *top* often describe positive qualities. Hence, they are placed above those words that include the concept *bottom*. In German, phrases like ‘am Boden zerstört’ (= *dashed to the ground*) and ‘mit hängenden Schultern' (= *with sloping shoulders*), contain the concept *bottom.* These phrases serve to express a person's sadness or their negative state of mind. The metaphors for the antonyms of these emotional expressions are placed on the upper half of this fictive ordinate. That means that, for example, a happy and successful person is often referred to as being 'an der Spitze' (= *in the forefront*) and as walking 'erhobenen Hauptes' (= *with head held high*). Persons who are in a higher position than others can be described as 'übergeordnet' (= *superior*). 'Oberkellner' *(=* *headwaiter*), 'Oberoffizier' (= *superior officer)* or 'Topmanager' (= *top executive*) are also common examples of expressions that contain spatial terms. The usage of spatial expressions for abstract concepts exists in several languages and hence seems to be cross-cultural.

However, these observations leave an important question unanswered. Where do we find the origins of this obvious global linking of *top* with *good* and of *bottom* with *bad*? Why do spatial words often, even though not always, convey an evaluative meaning? Schubert (2005) showed that people also tend to represent social structures and power relations in vertical spatial positions. Thus, these abstract concepts seem to be influenced by physical patterns and seem to be embodied. Schubert came up with the hypothesis that these concepts could already arise in early childhood development, when children generate certain mental representations of their parents and other closely associated persons. All these persons are bigger than the children. So, the feature *large* could easily be linked with *good*. As Schubert (2005, p.18) puts it, the difference in size between children and parents contributes to „the embodiment of power by verticality".

A similar hypothesis is articulated by Casasanto (2009) and closely linked to the early childhood imprinting suggested by Schubert. In early stages of their development, people could have learned that there is a connection between emotional experiences and the simultaneously emerging physical reactions. A sad person, for instance, tends to hang his head and to drop his gaze. In contrast to this, a person having a good and successful day will express this physically by walking with his head held high. Thus, our feelings impinge upon our posture. This influence contributes to the formation of mental metaphors like *top is good* or *top is good-humored* versus *bottom is bad* or *bottom is bad-tempered*. Consequently, these mental concepts also influence the way we speak and our choice of expressions. If this is true, mental metaphors would have become linguistic metaphors, which are universal parts of our active vocabulary and, hence, of our everyday life.

This hypothesis is not sufficient for answering the question of whether physical characteristics are the origin of linguistic metaphors that include spatial expressions. Since all people tend to hang their heads when they are sad or depressed and all people walk with their heads held high when they are proud of themselves, there is no reference group with which we could compare the results of "normal" people regarding the origin of their concepts *top is good* and *bottom is bad*. Thus, Casasanto (2009) suggests the *body-specificity hypothesis* as an appropriate tool. The assumptions made by researchers working on embodied cognition constitute the basis of this hypothesis. It expresses the idea that people with different bodies develop different abstract concepts of the same objects, and consequently that people with different bodies should also think in different ways.

> That is, if concepts and word meanings are constituted in part by simulations of people's own perceptions and actions, then people with different bodily characteristics, who interact with their physical environments in systematically different ways, should form correspondingly different mental representations. (Casasanto, 2009)

In order to illustrate this body-specificity hypothesis, Casasanto discusses the example of color-blind people from Simmons et al. (2007). This study showed that the mental representations of apples differ between persons with red-green color-blindness and persons who do not have this condition. A person who tries to imagine an apple does not only retrieve the shape and the size of this object. In order to complete this mental representation and simulate this object in his mind's eye, this person also has to retrieve the color of the apple. It is precisely this mental retrieval of the apple's color that leads to the difference between the mental representation of apples in persons who are red-green color-blind and those with normal color vision. Hence, the reason for the difference lies in the feature *color*, which is conceived differently when a color-blind person looks at an apple. This putative difference in the mental representations of apples seems intuitively plausible. Two persons looking at the same object will never create an identical mental representation of the object. Factors such as vision or body size, which also leads to a slightly different point of view being adopted, influence the perception of the object. It is highly likely, for instance, that a six-foot tall person would not see a small garden fence as a formidable obstacle, whereas the same fence would be perceived as insurmountable by a three-year-old child. Even though both are contemplating the same object, their mental representations of this object differ significantly.

However, Daniel Casasanto further suggested that such differences can also be observed in the mental representations of human motor functions. This claim presupposes significant differences in these persons' bodies, such as handedness:

> If thinking about actions involves mentally simulating the way we typically execute them, actions that we perform with our dominant hands such as throwing a ball, turning a key, or signing a check should have different neurocognitive representations in right-handed and left-handed individuals (Casasanto, 2009).

1.2 The abstract meaning of left and right in relation to handedness

1.2.1 An evaluation of the terms left and right

As discussed above, Casasanto (2009) suggested two possible answers to the question of why spatial expressions like *top* and *bottom* could evolve into evaluative linguistic metaphors. But how can we determine which of these hypotheses is correct? Casasanto suggested testing these two options on a concept which was universal, but which was not associated with the physical properties of a certain group of people. As Casasanto claims, such a concept can be found in the universal preference for the right rather than the left. This concept resembles the pattern of *top is good* versus *bottom is bad.* People similarly associate the *right* with positive abstract qualities like *intelligence* and *honesty* and the *left* with negative abstract issues like *stupidity* or *deception*. In common with the abstract concepts of *top* and *bottom*, these links also emerge in a large number of languages spoken all over the world.

The English language contains many idioms and phrases that make reference to these horizontal spatial concepts in the expression of abstract qualities. Passing an exam, for instance, is often accomplished by *giving the right answers*, in which case we could describe the student as *right on the button*. Students who are overwhelmed by the requirements of this exam might have been *left in the lurch* by their mental abilities and hence end up *out in the left field* (Casasanto, 2009). A good and caring person can be described as someone whose *heart is in the right place*. This phrase especially invites closer consideration inasmuch as it is, literally speaking, flat wrong, if the term *right* is interpreted as a spatial expression: the human heart is in fact usually located on the left side of the thorax. It could be argued that *in the right place* is simply a synonym of the phrase *in the correct place* and has nothing to do with the spatial meaning of the word *right*. The same might be true for the term *left*, which can also be interpreted as *quit* or as *remained*.

A closer look at the German language reveals that this objection does not seem to be tenable, since this language displays similarities in the case of these abstract concepts. First, speakers of the German language also use the phrase ‘das Herz am rechten Fleck haben’ (= *to have one’s heart in the right place*). This idiom has the same content as the English one – with one significant difference. The German version of the phrase contains the spatial phrase ‘am rechten Fleck’ (= *on the right-hand side*), which conveys that the heart is positioned on the right side of the thorax. Hence, this phrase cannot be translated literally as *in the correct place*, since the term ‘rechts’ only means *right*, whereas ‘richtig’ means *correct*. Of course, it is conceivable that the more logical formulation ‘am richtigen Fleck’ (= *in the correct place*) changed into ‘am rechten Fleck’ (= *in the right place*) arbitrarily or because of considerations of economy. If this were true, it would lead inevitably to the question of where the German word ‘richtig’ (= *correct*) emerged from. Is the apparent similarity to ‘rechts’ (the spatial expression *right*) merely arbitrary or does ‘rechts’ implicitly include the meaning of the word *correct*? The theory that horizontal expressions in German have the same abstract meaning as in English becomes even more likely when we consider the word ‘links’ (= *left*), which, as in English, has negative connotations. A clumsy person, for instance, has ‘zwei linke Füße’ (= *two left feet*) and somebody who is corrupt is described as ‘link’ in German, whereas a good or indispensable assistant is often described as ‘rechte Hand’ (= *right hand*). The terms ‘das Recht’ (= *law*) and ‘Gerechtigkeit’ (= *justice*) also include the word ‘rechts’, the German word for *right*. Despite the fact that the German words ‘rechts’ and ‘das Recht’ do not have the same origin[1], both terms are orthographically and phonologically effectively identical. This relationship suggests that both mental metaphors have emerged in the course of language change. Hence, it is highly probable that the concept *right is good*, which is also observable in the German language, can also be transferred to ‘das Recht’.

These principles are also applicable in French. Speakers of this language denote a clumsy person as ‘maladroit’. This example is highly interesting, since this word arises from ‘mal à droite’. This expression means literally that the person concerned is *bad at acting right* and, thus, contains implicitly the concept *left is inferior* and *right is superior and more important*. This issue becomes even clearer by considering the word ‘gauche’. The English equivalents for this word are *left, dubious* and *clumsy*. Consequently, ‘mal à droite’ and ‘gauche’ are synonyms, which both refer to the concept *left is inferior*. Justice, in this case, is – similarly to German – called ‘droite’ in French. This term can be translated with the spatial expression *right*.

However, these abstract concepts do not only emerge in combination with language. A closer look at the social conventions in the Western culture also

[1] ‘Rechts’ derives from the Latin word ‘dexter’, whereas the expression ‘das Recht’ originates in the Latin term ‘ius’. Although ‘dexter’ can be used as a spatial expression, it can also be translated as *lucky*. In contrast to ‘dexter’, ‘ius’ has an analogy in the English word *correct* (Pertsch, 2007).

reveals these concepts. In order to greet one another, people offer their right hands. Reaching out the left hand without a good reason is considered impolite und disrespectful. The validity of this principle can often be observed in situations in which a child reaches out the “wrong” hand with which to shake an adult’s hand. In all likelihood, the parents or guardians will rebuke the child for its error of proffering the “bad hand”. In other cultures this *left is bad* principle has an even wider influence. In Islam, using the left hand for food intake is strictly forbidden. Similarly, social conventions in Ghana, mandate that people are not allowed to perform deictic gestures with their left hands or direct the left index finger towards another person (Kita & Essegbey, 2001).

What distinguishes these concepts of *right is good* and *left is bad* from the previously described concepts *top is good* and respectively *bottom is bad*? This can be explained with regard to human anatomy. Section 1.2 presented the theory introduced in Casasanto (2009) that the bodily experiences that a person has exert a strong influence on the mental representations of this person. If this theory is correct, left-handers should have a lower or even nonexistent affinity for the right side. As a consequence, the universal concept *right is good* in language use would simply have emerged because of the overwhelming majority of right-handers in the Western culture, in which only one person out of ten is bodily left-dominant. These right-handers could have transferred their positive experiences with their dominant (right) part of their body to their everyday vocabulary. This could have led to the previously explained idioms. So, these given concepts *right is good* and *left is bad* might only be a product of the mental representations of right-handers. Left-handers, meanwhile, would have applied these concepts merely because they became a standard in language and culture. In this case, these concepts might, indeed, relate closely to the thinking and acting of right-handers, because they are originated by bodily experiences. However, for the left-handed part of mankind these concepts would merely be a figure of speech – and stand in stark contradiction to their mostly negative experiences with the right side.

If the second possibility suggested in Casasanto (2009) is the correct one, linguistic metaphors concerning the right or the left would have emerged arbitrarily. This scenario would entail that these concepts developed similarly in the mind of right- and left-handers, since the previously represented idioms were established arbitrarily over the course of time. On the basis of the permanent confrontation with certain linguistic concepts in a language, the speakers of the language would become accustomed to the underlying mental concepts and transfer them, as a first step, to their active vocabulary. In a second step, the mental concepts would penetrate their minds. By this mechanism, linguistic concepts would be converted into mental concepts. Consequently, idioms such as *two left feet* or *to put something right* would shape new representations that influence decision-making procedures even when these processes do not have anything in common with language. Due to this permanent confrontation, people would become conditioned that *right* is a synonym for *good* – and that this principle was true with reference to the whole world. Certainly this principle would also lead to the adoption of the belief that *right* was better than *left*.

The correctness of this theory would also imply that the belief that *right* was better than *left* would be independent of and unaffected by a person’s handedness. Essentially, it implies that the abstract concept should be equally pronounced in the minds of right- and left-handers. By definition, right- and left-handers would still have bodies with differently dominant parts, but the preference for the right would not be motivated by these physical differences, but rather by universal linguistic concepts, that were equally strongly developed in the minds of right- and left-handers. These hypotheses admit and call for experimental investigation.

1.2.2 The concepts of left- and right-handers

If Casasanto's first theory is correct, we must ask how these extremely different abstract mental representations could have emerged in the minds of right- and left-handers. Casasanto suggests early childhood development as the locus of the difference (Casasanto & Henetz, 2012). Children tend to realize in early stages of their development that just one of their two hands is able to perform fine motor tasks[2], whereas the other is already overloaded with simple tasks like tooth-brushing or painting. Nevertheless, children try repeatedly to optimize the abilities of their non-dominant part of their bodies, because they are not willing to accept this obvious physical restriction. Since this eager repetition is usually unavailing, Casasanto (2009) asserts that the process of trying must give rise to frustration and disappointment. Consequently, right-handers link these negative experiences caused by the dysfluent left side with negative emotions. As a result, the spatial expression *left* is mentally associated with this negative evaluation and comes to be used as a synonym of *bad* or *negative*.

Exactly the opposite occurs in connection with the right side of a right-hander's body. A child that tries to solve certain fine motor tasks with his dominant hand will experience a sense of achievement, since the abilities of this side of their body surpass those of the non-dominant side many times over. Writing, painting and throwing – all these tasks which are insoluble on the non-dominant side are unproblematic when performed with the right hand of a right-hander's body. In the course of time, right-handers connect more and more positive experiences with the fluent action of their right hand. Thus, these experiences result in the linguistic concept *right* being evaluated positively. As an example of this, Casasanto discusses research on the preferences of expert typists:

> … expert typists have shown a preference for pairs of letters that can be typed easily over pairs that are more difficult to type (even when typing is not relevant to the task), suggesting that motor experience

[2] Ambidextrous people are excluded from this assumption, because this small group of people is able to perform tasks similarly efficiently with both sides of their bodies.

> can influence affective judgments (Beilock & Holt, 2007; Van den Bergh, Vrana, & Eelen, 1990). In a sense, we are all “experts” at using our dominant hands. Perhaps over a lifetime of lopsided perceptuomotor experience, people come to implicitly associate good things with the side of space they can interact with more fluently and bad things with the side of space they interact with less fluently? (Casasanto, 2009, p. 353)

This theory seems to predict that right-handers’ and left-handers’ abstract concepts for the expressions of *right* and *left* should be entirely different. Nevertheless, it can be observed that right-handers and left-handers use the same linguistic concepts including these spatial expressions when literally describing areas on a horizontal axis. By common consent, idioms such as *two left feet* are used to describe a clumsy person, and there is no need to inquire into the speaker’s handedness in order to capture the correct meaning of this sentence. The mental representations of the abstract concepts *left* and *right* seem to be determined by a person’s handedness, but the linguistic concepts associated with these expressions appear to be unaffected by a speaker’s handedness. Thus, there is a strict congruency for linguistic concepts including spatial expressions.

Therefore, it is highly probable that left-handers have adopted these linguistic concepts of *right* and *left*, even if it stands in marked contrast to their mental representations of these concepts. This assumption suggests that the concept *right is good* has been chosen as the universal one because about 90 percent of humans are right-handed (Corballis, 2003). Consequently, this overwhelming majority have asserted the implicit right to transform their mental representations into linguistic metaphors. For reasons of simplification, everyone regardless of his or her handedness has been obliged to understand these idioms. The fact that left-handers have historically been retrained into right-handers, and were not accepted in many societies as recently as a few decades ago, corroborates this theory of a linguistic oppression of the left-handers’ abstract mental concepts (Sattler, 1995). Writing with the left hand was considered to be unpleasant and undesirable, just like reaching out the left hand in order to greet someone.

Right-handed people evaluated this behavior simply as a bad habit which could be eliminated with practice.

If Casasanto's (2009) body-specificity hypothesis is correct, the mental concepts of left-handers would indeed differ from the linguistic concepts they had to learn and have to apply. This assumption raises the question of whether unsatisfactory experiences with the right hand could have persuaded the left-handers that their non-dominant side is, in general, the worse side – the process that was argued earlier to take place in right-handers. Alternatively, it is conceivable that left-handers, having adopted these universal linguistic concepts of *right is good* and *left is bad*, unconsciously generate mental concepts which fit these principles.

As remarked earlier, the preference for the right hand is also applicable in social conventions. Reaching out the left hand in order to greet someone is taboo in Western culture, and food intake or writing with the left hand are completely forbidden in some other cultures. Given the existence of these conventions, it is plausible that left-handers have been turned into 'mental right-handers' in spite of all the negative experiences with their non-dominant hand. The permanent confrontation with a way of thinking and speaking established by a mostly right-handed society could have influenced the way in which left-handers judge the right versus the left. This might be especially applicable since left-handers are often forced to use their body in the same way as right-handers do in their everyday lives. Left-handers simply have to fulfill certain fine motor tasks with their right hand and consequently are frequently confronted with their physical differentness. For instance, conventional scissors, writing pads or potato peelers are made in order to be used by right-handers. A left-hander who suddenly has to use scissors and borrows them from his office neighbor will receive right-handed scissors nine times out of ten[3]. Consequently, a left-hander's environment makes him frequently conscious of the fact that he is part of a minority and has to cope with numerous constraints in his everyday life.

[3] Given that only about ten percent of people are left-handed, tools made especially for this group should be quite uncommon.

This leads us to ask which of the two influences is stronger for a left-hander: the positive experiences with the left hand or the negative experiences caused by this “different” body that does not fit a world dominated by right-handers and hence right-handed concepts, devices and rules? Or could it be that these opposite experiences lead to a mental neutralization, just as positive and negative quantities cancel one another out? In this case, left-handers should not judge *left* or *right* as *better* or *worse* – they should rather see these words only as spatial expressions without an evaluative meaning. Besides that, left-handers should not have a preference for the left side apart from writing and other fine motor tasks they tend to perform with their left hand. At least, a potential preference for the left should not be as extremely marked as would be expected of the right-handers’ preference for the right. This is due to the fact that social conventions and the problems with being part of a minority should weaken the effect of positive experiences with the left hand. Left-handers realize day by day that they do not conform to the norm because of their handedness, whereas right-handers live in a “right-handers’ world” that is tailored to this group of people and the way they use their bodies. Right-handed children are not encouraged to write with their left hand, nor is this described as the *good hand*. They use the right hand intuitively because it possesses fine motor skills. Consequently, it is entirely self-evident for this group of people to prefer the right hand and thus the right side.

In sum, the experiences that right-handers gain with their dominant side are positive in two respects – they are able to act confidently and fluently with this hand and they conform to the norm of handedness. However, these two positive experiences are gained much less consciously than is the case for left-handers’ negative experiences. Hence, it could be theorized that right-handers do not develop such well-marked mental concepts as left-handers, since they are not aware of the advantages intrinsic to the usage of their dominant hand. Being a right-hander is not seen as a privilege by this majority. It is simply a matter of course, which is neither to be evaluated as positive nor as negative. For that reason it could also be possible that neither group exhibits a large directional preference where abstract concepts are concerned.

1.2.3 Previous and current research

In order to substantiate the differences between the abstract concepts of right- and left-handers, a series of experiments has already been conducted. The results of these experiments seem to show that left-handers do indeed establish unconsciously the concept that *left is good*. Casasanto and Jasmin (2010) analysed video recordings showing politicians delivering speeches. The left-handed president of the United States, Barack Obama, and the right-handed former US president George W. Bush each used their dominant hand conspicuously often in order to emphasize positive utterances. By contrast, gestures performed with their non-dominant hand served to highlight negative utterances or were used to introduce unpleasant topics. In that respect, the gestures of the observed right-handers and left-handers seemed to be mirrored. Both groups used their dominant or *good* hand to emphasize positive aspects and their non-dominant or *bad* hand to highlight negative aspects. If these observations turned out to be universally valid, a speaker’s gestures and the hand he uses for a certain utterance could have the power to reveal hidden thoughts. For example, if George W. Bush evaluates the climate policy of other countries as insufficient, he would, in all likelihood, underline this topic with his left hand, although his words might convey a positive evaluation.

Casasanto and Jasmin also observed that right- and left-handers use their hands for the purpose of expressing two contrasting aspects of an issue – a positive one and a negative one. While talking about the negative facts, speakers gestured with their non-dominant hand. In order to emphasize positive aspects, they applied their dominant hand. From this Casasanto and Jasmin draw the following conclusion:

> It was not simply the case that people gestured more with their dominant hands. Rather, right- and left-handers also used their hands in contrasting ways when expressing ideas with positive and negative emotional valence, suggesting that they automatically activated contrasting associations between action and emotion. These data corroborate the results of laboratory tests showing that people implicitly associate good things with their dominant side and bad things with their non-dominant side. (Casasanto & Jasmin, 2010, p. 3)

Casasanto and Jasmin (2012) further explored these findings in the domain of typing, and discovered hints towards a potential “QWERTY-effect”. Most English-speaking people use the so-called QWERTY keyboard when communicating via typing. We can consider half of the letters to be situated on the right of the keyboard and half of them to be on the left. Inevitably, some words contain a greater proportion of letters on one side of the keyboard than the other. Casasanto and Jasmin investigated whether this difference, mediated through the action of typing, might give rise to differences in the meanings of the corresponding words. Three experiments were conducted in order to test whether asymmetries in the usage of the keys on the right and left side of the keyboard influence how people evaluate the emotional valence of the typed words. The findings hinted at the existence of a relationship between emotional valence and the side on which the typed letters were located. This QWERTY-effect seems to exist in several languages – and had the greatest magnitude in the case of pseudowords and words of recent origin.

Casasanto and Henetz (2012) investigated the abstract concepts of children as a function of handedness. The authors determined that different evaluations of the abstract meaning of *right* and *left* emerges in early childhood development. Thus, the evaluation of abstract concepts like *intelligence* or *kindness* should be different if these concepts were related to horizontal positioning. Casasanto and Henetz asked the young participants to sort toys into two boxes. One of these boxes was positioned to the right of the child, whereas the other one was positioned to the left. It turned out that the participants tended to sort their favorite toys significantly more frequently into the box on their dominant side, and their disfavored toys into the box on the non-dominant side.

However, this raises the question of whether the children placed the favorite toy next to their dominant side simply for practical reasons. The authors ran further experiments in order to investigate whether the children only wanted to position the superior toys next to them for the purpose of making them conveniently situated, or whether they chose the dominant side because this side matched their mental concept that *the good side is reserved for the good toy*. These experiments revealed that the mental link of *good* with *dominant* and *bad* with *non-dominant* persisted when the participants expressed their decision only verbally and thus without moving their body. To enable this test, the children were confronted with pairs of pictures of cartoon animals. One picture was placed on the right side and the other picture was placed on the left side. In this condition, the participants had to judge whether the right or the left animal was the nicer or more intelligent one. The results confirmed the hypothesis that positive attributes were associated with the dominant hand: the participants' preferences depended significantly on the side on which the pictures were placed. Hence, right-handed children rated the objects as being better when they were placed on the right side. By contrast, the left-handed children preferred objects placed on the left side.

Prior to Casasanto's work, former studies indicated that handedness does not become established until the age of eight (Corballis & Beale, 1976). However, Corballis and Beale claimed that a weak tendency for one part of the body can be observed in earlier stages. Nevertheless, a fixed handedness, which lasts for an entire lifetime, cannot be detected in children who are younger than eight. Casasanto, contrastingly, succeeded in showing that also children aged five were able to link positions on a horizontal axis with emotional valence. It turned out that all observed behavioral patterns also emerged in kindergarteners.

Casasanto and Chrysikou (2011) tried to create "artificial left-handers". The participants were asked to wear ski gloves on their dominant hand in order to reduce the fine motor skills of this hand. To increase the degree of difficulty, another ski glove was tied on the wrist of the participant’s dominant arm. In spite of this handicap the participants had to stack two chains of domino gaming pieces simultaneously – one with the handicapped right hand and one with the left hand. This made the participants feel as though they were “artificial left-handers” because their original dominant side became the weaker one and caused much more problems in solving the domino task. The preparation of the participants was designed to make the original dominant hand inferior to the non-dominant hand with its less marked fine motor skills. This handicap influenced the perception of the participants. This in turn affected the outcome of a later task, in which the “artificial left-handers” were asked to evaluate objects. The objects placed close to the non-dominant side of their bodies were preferred significantly often, whereas objects placed close to the dominant side were more often rejected, although this artificial imbalance disappeared after a while. Thus, Casasanto and Chrysikou succeeded in creating “temporary artificial left-handers”.

The first three experiments presented in Casasanto (2009) also corroborate the body-specificity hypothesis. These experiments explore the influence of evaluative terms on the choice of certain positions in space. The fourth and the fifth experiment of this paper, which dealt with the influence of handedness on decision-making procedures, were less definitive in their outcomes. In the first experiment the participants had to solve a drawing task. They were asked – similarly to the first experiment of Casasanto and Henetz (2012) – to draw animals in boxes. The participants were told which of two animals was the smarter, better, or more sympathetic one. They did not reveal their individual likes and dislikes but had to judge in place of a visitor of a zoo, who was going to see these animals (Figure 1).

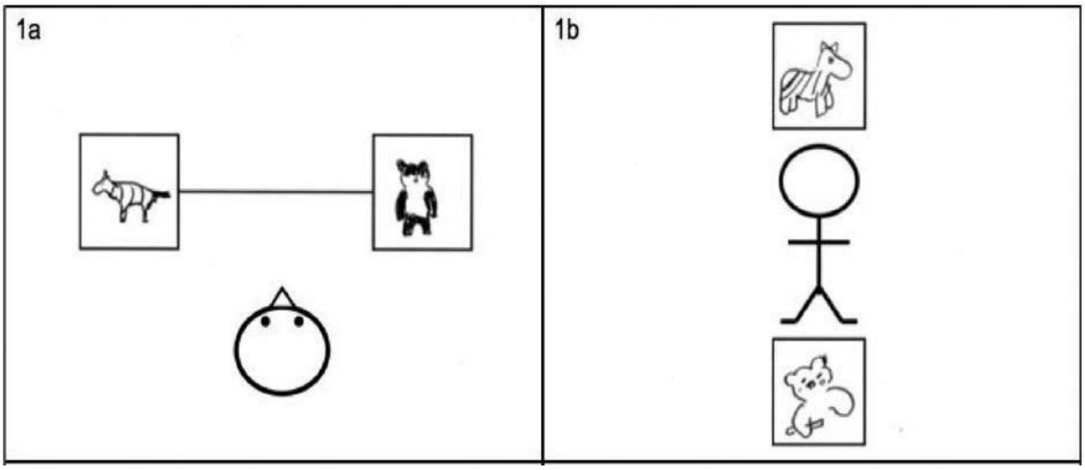

Figure 1: Examples of stimuli in the zoo experiment (Casasanto, 2009).

Casasanto designed two conditions of this task. In the first condition, the two empty boxes were placed one above the other. In the second condition, these boxes were positioned side by side on an imaginary horizontal axis. People tend to draw the *better* animal in the upper box, as the previously discussed vertical mental metaphors would lead us to expect. Similarly, in the horizontal case, the participants tended to draw the preferred animal in the box closer to their dominant side. Consequently, the results again supported the body-specificity hypothesis.

The second and the third experiment in Casasanto (2009) also dealt with the influence of descriptions on placement, and served as extensions of the first experiment. In the second experiment, the participants were asked to draw the previously described animals into the boxes. After doing so, the participants were asked to guess the purpose of the drawing task. The results provided an almost exact replication of experiment 1, and the follow-up question revealed that only 1% of participants correctly guessed the motivation for the experiment.

Nevertheless, it could still be argued that the participants chose the side for the simple reason that their bodies were actively involved in the task performance, since drawing animals into boxes requires movements of the dominant hand. Thus, it is conceivable that the observed effect only arose for reasons of comfort – right-handers are able to draw on the right side of a sheet of paper with minimal effort. That is why this side could be seen as being the better one for the superior animal. Therefore, the third experiment examined whether the answers would still be the same if the participants simply had to express their decisions verbally instead of drawing the animals. The findings were still significant, but not as convincing as in the previous two experiments. A large majority of the left-handed participants still chose to place the preferred animal into the left box, but the right-handers only displayed a slight tendency towards putting the better animal into the box placed closer to their dominant side. This raises the question of whether the participants in the previous variations of this experiment displayed such a strong inclination because they associated their dominant side with *good* or merely for the reason that they acted with this side of their body. The latter option would imply that the participants simply made their decisions for reasons of convenience.

The last two experiments in Casasanto (2009) were dedicated to investigating how placement exercised influence over the evaluation of objects. In the first of these experiments, the participants had look at a list with different pairs of so-called Fribbles[4]. They then had to judge, which Fribble out of each pair seemed to be the more intelligent or more sympathetic one. Within each pair, one Fribble was placed on the right side of the questionnaire, and the other one on the left side (Figure 2).

[4] Fribbles are alien creatures, designed by Michael J. Tarr, Brown University (www.tarrlab.org).

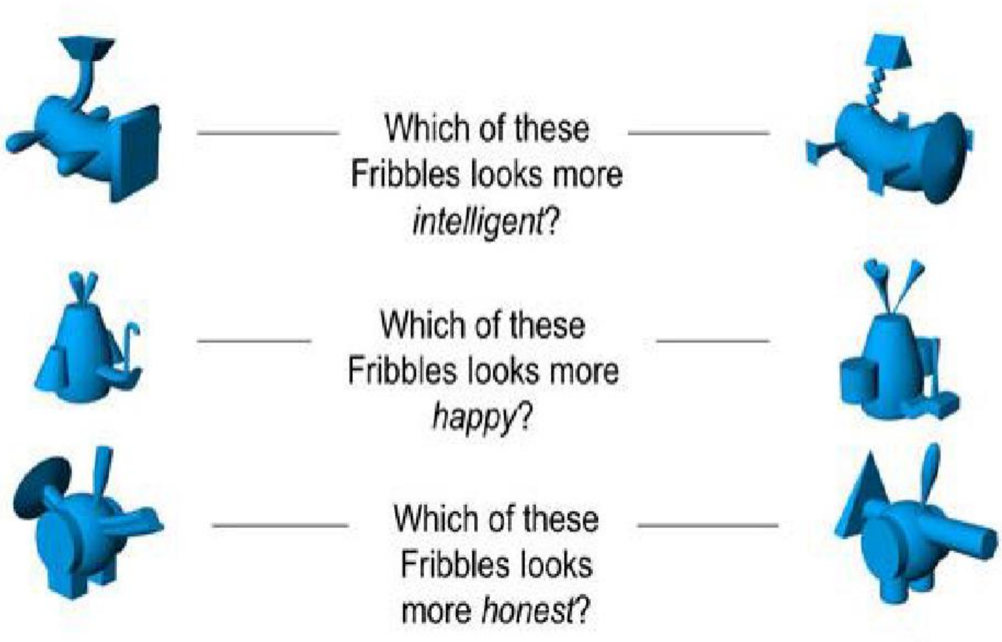

Figure 2: Examples used in the Fribble experiment in Casasanto (2009).

It became apparent that the participants were not as greatly affected by the side on which the Fribbles were placed as the authors seemed to expect. The effect was only significant at the .05 level. Moreover, the effect was caused solely by the small group of left-handed participants, whereas the right-handed participants only revealed a small tendency for preferring objects placed on the right side. Nevertheless, it is possible that the results only occurred on the basis of Casasanto's way of analysis, as will be discussed in more detail later in this thesis.

The second experiment that dealt with placements and their influence on decision making processes also revealed a bias for the dominant side. But, as seen in the Fribble task, this bias was not as well-marked as expected. In this last experiment, the participants got the task of going on a *Shopping Tour*. The design of this experiment was similar to the fourth experiment. The only difference was the absence of alien-like creatures. These creatures were substituted by semantically identical product descriptions. The participants had to imagine they would choose one of two possible brands out of each product category.

1.2.4 Two different types of experiments

It is clear that two different types of experiments were implemented by Casasanto and colleagues: *active placement experiments* and *perceptual judgment experiments*. Table 1 depicts how the described experiments can be classified into these groups.

Type I: Active placement	Type II: Perceptual judgment
A trip to the zoo	Shopping Tour
A trip to the zoo (+ awareness test)	Fribbles
A trip to the zoo (verbal version)	“Which toy is smarter?”
The QWERTY-effect	
Spontaneous Gestures of Politicians	
“Put a toy into a box!” (children)	
“Put a toy into a box!” (hemiparesis patients)	
Glove experiment + toy placement	

Table 1: Distribution into active placement and perceptual judgment experiments

It is striking that there is a strong imbalance in the distribution. So far, Casasanto has performed eight versions of *active placement experiments* and only three versions of *perceptual judgment experiments*. This imbalance might be explained by an observation which is applicable to all the experiments within one group. The results of both types of experiments showed significant handedness effects. However, in the case of the perceptual judgment experiments the effects were only significant at the .05 level. Moreover, the effects in these experiments were caused solely by the small group of left-handed participants. This raises an important question: what is the reason for these obvious differences in the results of the active placement experiments and the perceptual judgment experiments? To obtain a more robust estimate of the statistical reliability, we performed a replication of one of the central perceptual judgment experiments, the *Shopping Tour* (Casasanto, 2009).

2. The Shopping Tour

Is the impact of handedness so strong that it determines the outcomes of decision-making tasks? In the following, I will investigate the actual impact of handedness on the mind. In order to establish a basis for my investigations, I will take a closer look at one of the experiments described under the title "Body-Specific Decisions about the Office and Marketplace" by Casasanto (2009). For simplicity, I will refer to this experiment as the *Shopping Tour.* Although Casasanto discussed two experiments, I will focus on the one about product descriptions because of its greater external validity, and will only briefly discuss the other experiment (concerning job applicants). After explaining the data in more detail, I introduce another interpretation of the existing data and provide an improved design for replicating the results.

2.1 Method

2.1.1 Materials and procedure

The *Shopping Tour* experiment was conducted with 371 English-speaking students from Stanford University and the University of California, Riverside. 321 of these participants were right-handed; the remaining 50 were left-handed. The description of this experiment (Casasanto, 2009) suggests that the participants provided only a verbal indication of their handedness. However, handedness is crucial for this experiment. Thus, the *Edinburgh Handedness Test* (Oldfield, 1971) would have been an appropriate tool with which to check the participants' handedness. As discussed in chapter 1, the experimenters first administered a questionnaire to ask participants to make a series of decisions as to which of two products they would prefer. Importantly, these products were described in different but semantically equivalent terms. Thus, the experiment tested the impact of handedness rather than the description of these products.

The questionnaire consisted of six items. For each item, one set of descriptions was placed on the right-hand side of the product name and the other set of descriptions was placed on the left. Table 2 displays two of these product categories. I am grateful to Daniel Casasanto for being so kind as to provide the raw data from all 371 participants for this research, and enabling me to adopt these product categories for a replication of this experiment.

kills germs fresh-scented moisturizes hand	**DISH SOAP**	antibacterial clean smelling conditions skin
money back guarantee physician recommended affordable luxury	**MATTRESS**	unconditional warranty physician approved luxurious and affordable

Table 2: An excerpt from the original *Shopping Tour* questionnaire

As a first step, I will analyse the first category displayed in Table 2 in more detail. This category displays the item *dish soap*. In this item the participants had to decide between one type of soap with the properties *kills germs*, *fresh-scented* and *moisturizes hand* and a different one with the features *antibacterial*, *clean smelling* and *conditions skin*.

Following the first part, there was another set of items. However, this set was focussed on job applicants. Each job description (e. g. programmer) was paired with two sets of words describing the applicant. Similarly to the previous procedure, the participants saw one of these job titles and the descriptions of two job applicants in each line. One of these descriptions was placed on the right side of the category name, and the other description was placed on the left side. The participants had to decide which of the two applicants was most suitable. Importantly, the descriptions of the applicants were said to be semantically equivalent. For instance, the participants had to decide between *an engineering major from Virginia Tech who programs in Perl* and *a math major from Georgia Tech who programs in Python*. Thus, as argued by Casasanto (2009), the only criterion which made these two options distinguishable was the side on which the description was placed.

Casasanto used four different versions of the original questionnaire, which displayed the categories mirrored and in two different orders. Thus, the presentational aspect of the procedure was varied, controlling for any potential differences of meaning that might have been perceived between the two sets of descriptions. After the participants had chosen one of the two options for a category, they had to mark their decision in a certain way: specifically, by circling the preferred option and crossing out the rejected one.

2.1.2 A closer examination of the *Shopping Tour* design

In the previous chapter I discussed the design and the implementation of the *Shopping Tour* in Casasanto (2009). This detailed description revealed several aspects which could have influenced the experiment and confounded the results. For instance, information about the handedness of the participants was only obtained by asking them which hand they use to write with. However, the participants recruited for the *Shopping Tour* consisted solely of students and, hence, people, who were born in the 1980s. It is possible that some grew up at a time and in a cultural setting in which it was common for left-handers to be retrained into right-handers. These becomes more likely when we recall that Western society traditionally considered the left hand to be “dirty” and “bad”, a way of thinking that started to change only a few decades earlier (Sattler, 1995).

Likewise, the participants were not interviewed as to their nationality or their cultural background. This could also diminish the applicability of the results, since the participants could have grown up in a culture that still does not acknowledge the existence of left-handedness and prohibits the usage of the left hand for certain fine motor tasks. Given this possibility, the experimental participants might include more numerous natural left-handers than the number reported by Casasanto (2009). Since a person could have been retrained into a right-hander, the hand with which the person writes does not necessarily furnish correct information about this person’s real handedness. Using the *Edinburgh Handedness test* could have addressed this issue, in addition to detecting ambidextrous people, i.e. those who show little or no preference in the use of their hands. Ambidextrous participants can provide valuable insight for the investigation of the body-specificity hypothesis because these participants are neutral in terms of preferring one hand over the other. Thus, any handedness-related effect in ambidextrous people cannot be attributed to the body or to physical ability but must be attributed to external influences.

In addition, the strong mismatch in the number of left-and right-handers could also have led to misinterpretations. As stated in the detailed description of the *Shopping Tour* in section 2.1.1, the right-handers (321 participants) outnumbered the left-handers (50 participants) by more than a factor of six. Thus, the results obtained from the 50 left-handers cannot be as informative as those obtained by the 321 right-handers. It is likely that the problem of the low number of left-handers was caused by the method by which participants were recruited for the *Shopping Tour*. No especial effort was made to recruit left-handers to take part in this experiment, presumably because this would have made the purpose of the experiment more obvious to the participants and thus risked distorting the results. Instead, the experiment was performed with randomly recruited participants, some of whom just happened to be left-handed. Therefore, the ratio of 50 to 321 is not surprising, since the proportion of left-handers in the *Shopping Tour* experiment (13.5 percent) corresponds closely to the proportion of left-handers in the general population (estimated at around ten percent; Corballis, 2003).

Nevertheless, this natural distribution of participants could have been circumvented. For example, the quota sampling method could have been applied. This method would have required the controlled recruitment of participants belonging to all three groups of handedness, until a certain number of right-handers, left-handers and ambidextrous participants had been achieved. This procedure calls for the preselection of potential participants, which could quite easily have been performed by observing the participants writing or eating. Of course, this procedure does not replace the *Edinburgh Handedness Test*, since the real handedness could still differ from the handedness observed in participants' performance of fine motor tasks.

Another problem with the implementation of the *Shopping Tour* concerns the pairs of terms that were used to describe the two different brands within a particular product category. As explained with reference to Table 2, it was claimed that both descriptions within one product category should be semantically identical. This immediately raises the question of whether it is possible to find two descriptions of the same item that truly are exactly identical. According to semantics, it is not. That is mainly because it is always necessary to distinguish between the intension and the extension of certain expressions. This semantic difficulty can be illustrated with reference to the so-called *Morning-Star and Evening-Star* issue (Carnap, 1947; Frege, 1892). The intension or the inherent expression of the term *Morning Star* is 'a celestial object that is visible in a certain location in the morning. However, the expression *Evening Star* contains the intention of 'a celestial object that is visible in a certain location in the evening'. This example discloses the existence of more than one intension related to a single extension. This extension is a single object in the world that these expressions are referring to, which in this case is the planet Venus. Hence, the extension is the same, but the intension varies. In a similar way, speakers of the same language could evaluate two terms differently and create two different intensions corresponding to the same extension. Consequently, in the participants' view, the reference object would be the same in both cases, but they would nevertheless develop different mental representations. After all, the term *Morning Star* incorporates the concept of *early in the day*. So, if somebody would call the planet Venus the *Evening Star*, when seeing it in the morning, this would be a mistake – although the reference would still be correct.

Casasanto eliminated the influence of possible inconsistencies in content by creating four counterbalanced versions of the questionnaire. That means that he mapped the pairs of descriptions in a different order and mirrored them on the response sheets. Still, the possibility persists that the – generally vanishingly small – difference in semantic content played a significant role in contributing to a decision for one of the two products. If a participant has to evaluate the two brands in the product category *dish soap*, it is striking that *kills germs* as opposed to *antibacterial* has a well-marked difference semantically. While the term *kills germs* is primarily used in the field of vernacular or oral communication, *antibacterial* is associated with technical language and therefore might be a foreign word for some people. Hence, it is likely that many participants would tend to prefer the product described as *antibacterial* because this word is associated with a higher register of language, and this in turn suggests that the product is of higher quality. Furthermore, the participants might process the verb phrase *kills germs* in a different way than the adjective *antibacterial* because these two terms have different semantic origins. More precisely, the term *kills* contains an extremely radical abstract concept. The phrase *kills germs*, therefore, expresses that the product described with this term is able to kill bacteria actively. The alternative, conversely, carries the prefix *anti-*, which only expresses that this particular product diminishes the impact of germs. In short, the meaning of these two terms is different for a number of reasons.

The same semantic problem can be observed in the case of the example *mattress*. A *money back guarantee* is more transparent for a potential customer than an *unconditional warranty*. In the first case, customers can be sure that, in the event of their returning the product, the purchase price would definitely be refunded. Hence, the manufacturer of this product seems to be expressing a high degree of confidence in the quality of the product, which conveys an indication that a good decision has been made in buying the product. The meaning that is conveyed by the phrase *unconditional warranty* is less clear. It suggests that the manufacturer is less accommodating, and is merely willing to replace a faulty product with another or offer perhaps a partial refund. Consequently, the choice of the product with an *unconditional warranty* might be associated with a higher risk, in which the customer purchases a potentially inferior product. A similar difference is manifest in the terms *physician recommended* and *physician approved*. On closer inspection, the item that is *physician recommended* is a better choice; this is a stronger statement than *physician approved*. The product with the former description is – literally speaking – recommended by a doctor, who is implied to have tested and consequently approved this product before this recommendation. Approval is only a necessary condition for a recommendation, and by itself only suggests that the product meets the current standards. Such a product may not be worthy of an explicit recommendation.

The participants had to express their decisions by drawing either a cross or a circle on the questionnaire. It is highly probable that this *cross-versus-circle* method was chosen in order to exclude the possible influence of motor activity on the participants' decision. Otherwise, a far-reaching problem might have emerged. If the participants marked only the preferred product and left the dispreferred product unmarked, another possible interpretation of the results would have been feasible: namely that participants preferred the item that was closer to the dominant hand and thus easier to reach. Consequently, without this method, the experiment could not have addressed the central question of whether the subjects chose the product placed on their dominant side because they linked *dominant* with *superior* or whether they did so merely for reasons of physical economy. Even so, the method raises another question: were the two symbols, the cross and the circle, equally easy to draw? If the motor efforts involved were different, we might expect participants to draw the more difficult symbol on their dominant side, as this allows a more comfortable hand position and thus compensates for the increased difficulty.

2.2 Analysis

2.2.1 Description

The analysis of the *Shopping Tour* revealed that 272 of 371 participants showed either a preference for right or for left. 99 participants (27 percent of the total) chose the same number of product descriptions on each side. These participants, who exhibited no preference, were excluded from further analysis. In Casasanto (2009) this decision was explained as follows:

> The proportion of participants who showed no preference did not differ as a function of handedness (30% of left-handers, 26% of right-handers), $\chi^2(1) = 0.18$, Fisher's exact *p*rep = 0.62, so these participants' data were excluded from further analysis. (Casasanto, 2009, p. 359)

The problems with this rationale will be discussed below in more detail. In the case of the remaining 272 participants, 74 percent of the left-handers revealed a preference for the left side, whereas a slight majority of 52 percent of the right-handers preferred the right side. Thus, via this method of analysis, a correlation could be shown between the choices and the participants' handedness, which was interpreted as a preference for descriptions positioned on the dominant side.

2.2.2 Criticism of the analysis

Certain steps of the analysis of the *Shopping Tour* experiment raise important questions. A crucial point is the exclusion of 99 participants from the analysis. As stated in section 2.2.1, this group was excluded because these participants recorded the same number of circles and crosses on each side and consequently showed no preference for one particular side. However, this justification is highly doubtful. The decision was defended on the basis that an approximately equal percentage of right- and left-handers (30 percent of the left-handed subjects and 26 percent of the right-handed subjects) had no preference for one side over the other. However, the relation between this observation and the decision to omit these subjects without a preference is tenuous. Why does this similarity justify the exclusion of the participants' data? Why is it so substantial that nearly the same number of right-and left-handed showed no preference? This issue assumes particular importance when we recall that nearly as many right-handers preferred the left side as the right, as I will argue in the following.

As already discussed, in Casasanto (2009) it was hypothesized that right-handed people often ascribe a higher value to the right-hand side because of the good experiences associated with the right side of their bodies. In the case of the left-handers the exact opposite applies. However, this would also imply that those participants without a preference implicitly falsified the body-specificity hypothesis, or at least that their results should be weighed as evidence against this hypothesis. In defiance of body-specificity, this group of participants were apparently unaffected in their decisions by the side on which the products were placed. This argument obliges us to challenge the justification for omitting these 99 subjects. The exclusion of these participants, on the basis of their results, has the effect of artificially increasing the statistical significance of the tested effect. That is because this procedure removed data points which otherwise would have reduced the significance of the handedness effect.

According to Casasanto (personal communication), the effect in the *Shopping Tour* experiment was in fact only weak[5], but the same experiment run with children as participants elicited much stronger effects. A reason for the success of this variation of the *Shopping Tour* and the failure of the same experiment with adult participants was not specified. Nevertheless, on the basis of this experience, Casasanto suggested replicating this experiment only with young participants, in order to achieve a significant effect.

[5] Daniel Casasanto consented to answer some of the unacknowledged questions concerning the *Shopping Tour* experiment in an e-mail correspondence. In this case, he admitted that this experiment was not as convincing as many other experiments performed to prove the body-specificity hypothesis.

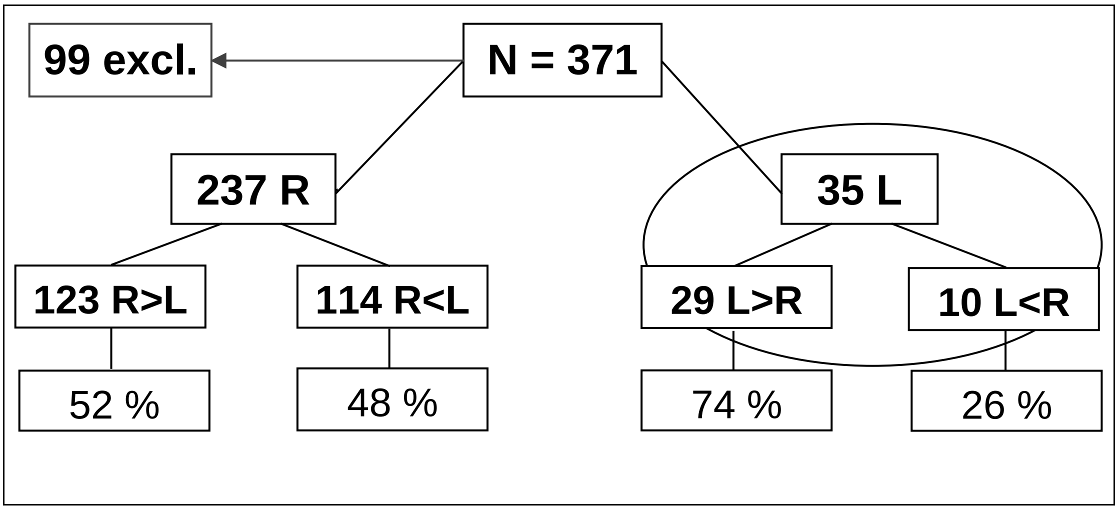

Figure 3: Results of the original *Shopping Tour* experiment

Figure 3 illustrates the results of the *Shopping Tour* experiment as a tree diagram. These results were also presented in Casasanto (2009) and they show, as previously discussed, that the number of participants that were included in the analysis was reduced from 371 to 272. Despite the manipulation, the experiment did not have the required power. Even once 84 right-handers without a preference were excluded from the analysis, only 52% – a very narrow majority – preferred the right side when choosing the products in the questionnaire. After the elimination of 15 left-handed participants with no bias, the remaining left-handers exhibited a strong bias for the left side, with 29 of the 35 participants (74%) preferring a majority of products on that side.

This procedure reveals two problems. The first one is the small number of left-handers. After the elimination of those left-handers with no preference only 35 left-handed participants were considered in Casasanto's analysis. In contrast to the 287 right-handers this number seems to be extremely low and raises the question of whether such a small sample could be judged as representative. Even then, ten of the left-handed participants showed a tendency towards choosing more products positioned on the right side of the questionnaire. Thus 26% of the small cohort of left-handers refuted the body-specificity hypothesis (excluding those who exhibited no preference, who could also be argued to refute the hypothesis). Of course, still 29 participants confirmed it.

This analysis drew attention to a further problem with the original analysis of the experiment. After excluding the 15 neutral left-handers, only 35 left-handed participants remained. However, the original version of Figure 3 stated that 29 left-handers preferred the left side and 10 the right, for a total of 39 participants. Casasanto was able to confirm that the published data contained a calculation error, which introduced this discrepancy. The corrected figures are shown in Figure 4.

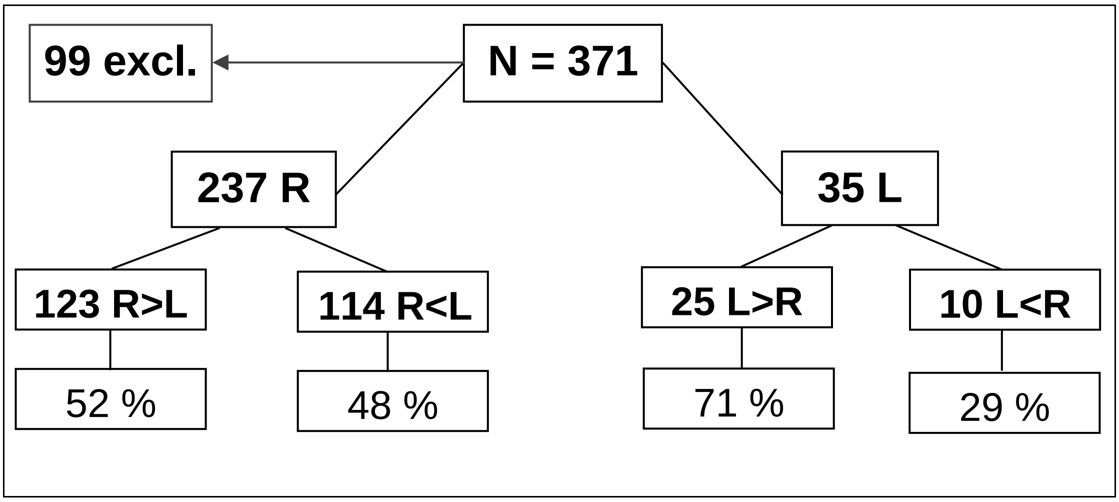

Figure 4: Corrected results of the *Shopping Tour* experiment

There were indeed 35 left-handed participants who exhibited a preference one way or the other. Of these, 25 preferred the left-hand side and 10 the right-hand side. Thus, in fact, 71 percent of left-handers preferred the left side, and 29 percent of left-handers preferred the right (see Figure 4a).

Despite this correction, there remained a two-thirds majority of left-handed participants, who showed a preference for their dominant side while working with the questionnaire. The evaluation showed that, despite this change still a significant difference existed. This difference pointed towards how the group of left-handers as opposed to the group of right-handers performed in answering the questionnaire ($\chi^2(1, N = 272) = 6.641$, $p = .01$, $\Phi = 0.16$). However, the smallness of the group of left-handers is reflected in the small effect size, as expressed by Cramer's Phi[6]. That implies that the effect is

[6] Cramer's Phi takes different values depending upon the effect size, and can be interpreted as follows. Values of about 0.1 represent a small effect. Values of about 0.3 represent a medium effect. And values of about 0.5 represent a large effect (Cramér, 1999).

significant, but the strength of the relationship between both groups is quite low.

As a final step I will now restore into the analysis the previously excluded 99 participants who showed no preference for the right or the left side. This procedure creates an entirely new distribution, which is shown in Figure 5.

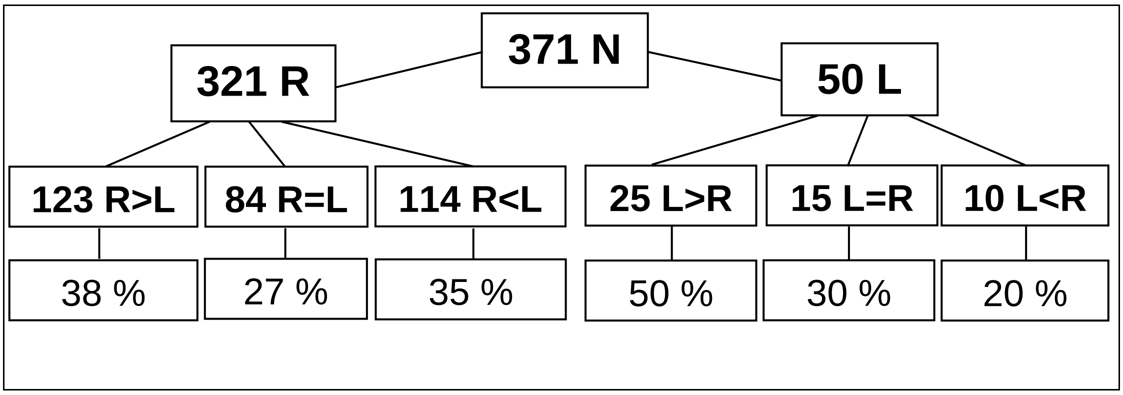

Figure 5: Reanalysis of the *Shopping Tour* results

In the case of the right-handers, this change leads to a strikingly different distribution. In this reanalysis, we see that only 38% of all right-handed participants revealed a preference for the right side. Assuming that all those participants without a preference for the dominant side can be considered to refute the body-specificity hypothesis, 62% of participants did so. This suggests that only the elimination of these 99 participants had led to the described handedness effect in the Shopping Tour experiment – and thus to the experiment being interpreted as supportive of the body-specificity hypothesis. Without this elimination the effect is – at least in the case of the right-handed participants – almost non-existent.

In the case of the left-handed group, the consideration of the previously excluded 15 subjects led to a marked shift in the distribution. If we divide left-handers into three preference groups (the left-preferring, the right-preferring and those subjects without preference), the largest group with 25 participants (50%) is the group with left-preference, as predicted by body specificity. Nevertheless, the observed effect of handedness on preference is still barely significant (χ^2 (2, N = 50) = 6.71, p = .035). Moreover, if we group the neutral and right-preferring left-handers into one single group, the resulting distribution is totally uniform: exactly half of the participants act in accordance with the body-specificity hypothesis and exactly half do not. As discussed earlier, I argue that this procedure is valid on the basis that participants without a clear preference are acting contrary to the predictions of the body-specificity hypothesis. From this perspective, it is first clear that no strong effect could be observed in these experimental data without the exclusion of the 99 participants with no preference. It is equally clear that the untrimmed, raw results would *prima facie* have contradicted the body-specificity hypothesis completely.

2.3 Re-Analysis

The more detailed discussion of the results of the *Shopping Tour* still leaves the main question unanswered. That is, on precisely what basis did the participants decide how to place their crosses and circles on the questionnaire? If a preference for one side does exist, this preference can differ in strength between individuals. It is possible that a participant might only exhibit a slight preference for the right or for the left side. This could have been expressed in, for instance, choosing five objects on one side and seven objects on the other side. Other participants, meanwhile, might exhibit a stronger preference, and could correspondingly select all twelve products from the same side of the questionnaire.

In Casasanto (2009) the extent of a potential right- or left-preference remained undiscussed. A precise 6-6 split in responses led to the exclusion of the participant from the analysis, as discussed above. However, participants who deviated from this pattern in a particular direction were grouped together, irrespective of the strength of their preference. Examination of the size of participants' biases might have provided a useful basis for drawing conclusions about whether their preferences were stable or potentially random in origin. Thus, a more definite result might be achieved by analysing the original data from the *Shopping Tour* experiment in a certain way. The exact distribution of the selected products on the questionnaires should be included into the analysis rather than just the tendency for a particular side.

I performed such an analysis on the original data, which was provided by Daniel Casasanto. For each participant, I considered their degree of deviation from the uniform distribution. I then computed a new statistic, which I will refer to as *bias*. This is defined such that a negative value corresponds to a preference for the left and a positive value corresponds to a preference to the right. The magnitude of the value indicates the strength of the preference.

Bias is calculated by taking the number of objects selected from the right side, subtracting the number of objects selected from the left side, and halving the result. For this experiment, bias thus falls in the range [-6, +6], with a value of +6 applying to participants who selected all 12 items from the right of the questionnaire and a value -6 applying to participants who selected all 12 items from the left of the questionnaire. Zero bias indicates that the participant selected 6 items from the left and 6 items from the right of the questionnaire.

The resulting bias for the left-handed participant is plotted in Figure 6. Considering this distribution, we see that only a very slight tendency toward the left emerges in the decisions of left-handed participants. This phenomenon is illustrated in Figure 6.

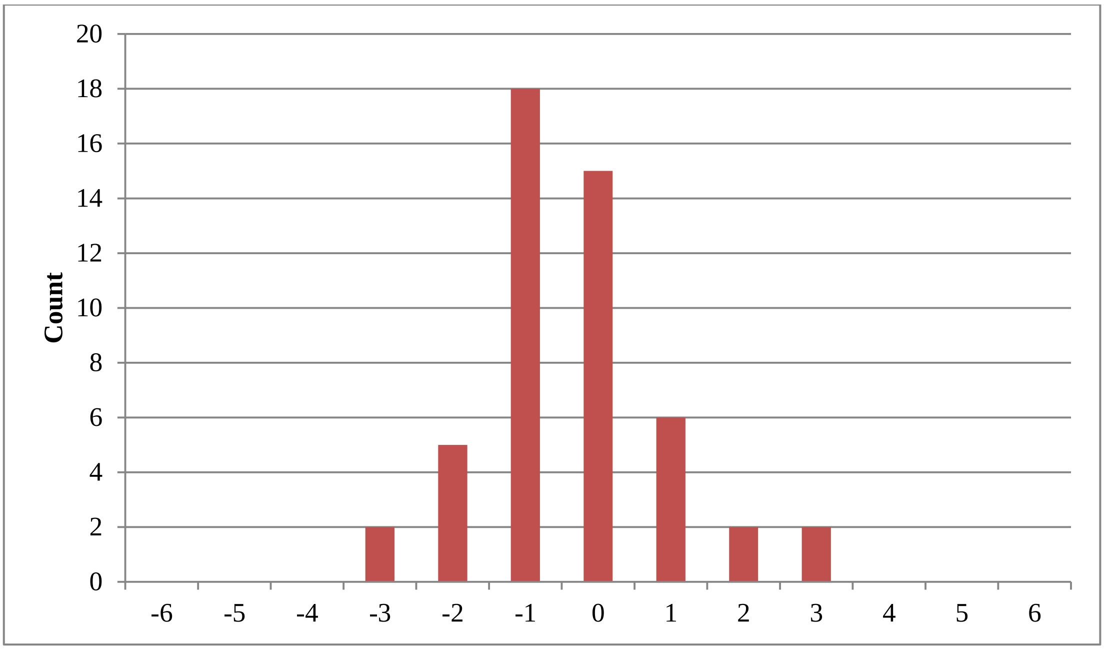

Figure 6: Bias of the left-handed participants

It is striking that 39 out of the 50 left-handers showed no preference or only a very slight preference in their choices (bias magnitude 0 or 1). As already discussed, 15 of the left-handed participants chose exactly six objects on the left and six objects on the right side. A deviation of only one object from this balanced distribution towards the left side was shown by 18 left-handed participants, while six participants showed the same slight deviation towards the right side of the questionnaire. These figures already indicate a strong concentration on the mean. This is also suggested by the diagram in Figure 6, which approximates a Gaussian distribution.

A statistical computation of the mean values that includes all left-handers confirms this assumption. This mean value of the left-handers averages -0.36. This result does not significantly differ from zero under a t-test ($t(34) = -1.999$, $p = .54$).If we define a tolerance value of 1 to be applied to the bias, we find that only 11 of the 50 left-handed participants showed a distinct preference for one side or the other, and of these 7 preferred the left and 4 the right (not a significant difference, if we apply the sign test).

In the case of the right-handers, this approach discloses an even less pronounced handedness effect. In this case the mean value is positioned at

0.05 (t(236) = 0.483, p = .629). The diagram shown in Figure 7 once again approaches a Gaussian distribution.

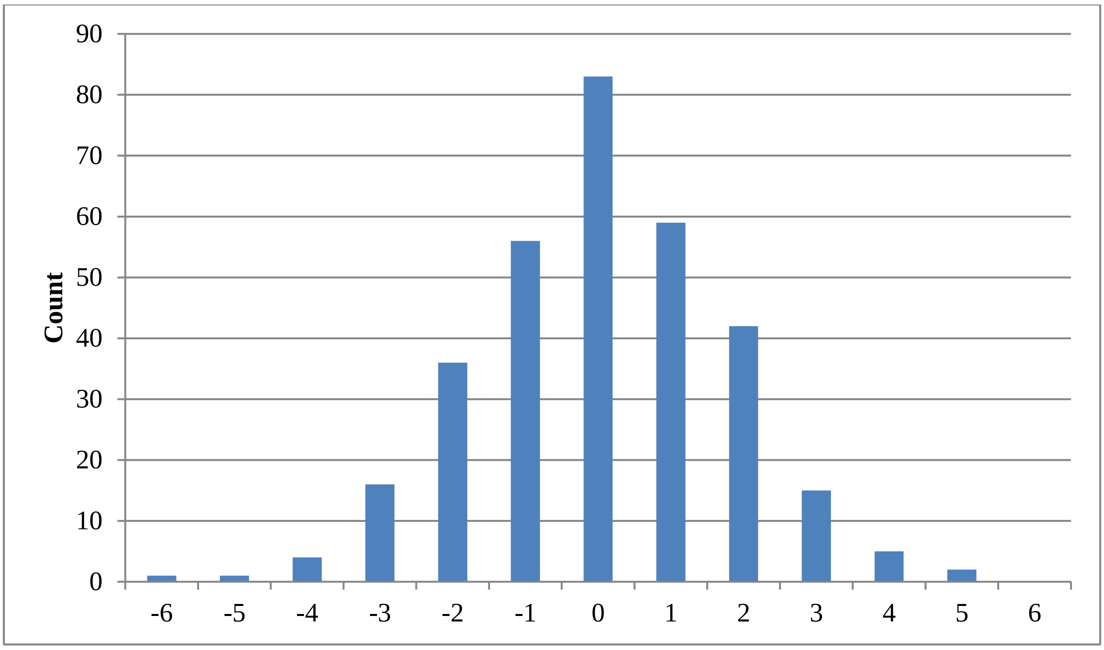

Figure 7: Bias of the right-handed participants

As Figure 7 reveals, 198 of the 321 right-handers fall within the previously set tolerance range (exhibiting a bias of magnitude 0 or 1). Of these, 59 selected seven items from the right side, but 56 selected seven items from the left side. Only 121 of the 321 right-handers showed a more pronounced preference for one side, with 64 revealing a clear tendency to the right and 58 to the left. It is striking that precisely one participant chose only those objects that were positioned on the left, but no participant did the opposite. Throughout the analysis, no significant preference for one side over the other is visible. The participants' mean bias values reflect this, showing no significant difference from zero (t(271) = -0.092, p = .926).

Pooling all participants, does a bias emerge? The question can be answered in the negative (t(369) = 1.592, p = .112). Thus, this more detailed analysis of the data disclosed by Daniel Casasanto reveals that very little evidence of handedness effects emerges in the Shopping Tour. Thus, this experiment produces no proof of the claim that the side on which the descriptions of the products were displayed exerted an influence on the participants' decisions. The slight effect that appears in the original analysis is due entirely to the behavior of the small sample of left-handers and appears credibly attributable to chance.

This reanalysis invites the question of whether products with certain descriptions were chosen on the basis of significant but unacknowledged semantic differences between the two sets of options. This would imply that the participants were not influenced in their decision making processes by the side on which the objects were positioned, but by more substantive semantic factors, as discussed earlier in this chapter. This question cannot be answered on the basis of Casasanto's original data: the results record only how many objects each participant selected from each side of the questionnaire. It was not documented which description led to which decision.

3. Experiment I: The replication of the *Shopping Tour*

As explained in the preceding chapter, the *Shopping Tour* experiment of Casasanto (2009) raises various questions. In particular, the results suggest that further investigations could be useful to clarify the influence of handedness in perceptual judgment tasks. For this reason, I decided to run a replication of the Shopping Tour experiment.

Contrary to Casasanto, I hypothesize that this replication will reveal that the side on which the descriptions were placed does not affect the decisions that are made. First, the detailed analysis of the original Shopping Tour experiment indicates that the distribution of preferred products does not stand in any obvious relation to handedness. Secondly, the process of reading product descriptions involves a large number of distinct factors, any of which might influence the participants' decisions. These influences could contribute to variability in the results, which might be misconstrued as evidence for handedness effects. The null hypothesis for my study will be explained more detailed in the following. Additionally, since some aspects of the original experiments turned out to have room for improvement, I also decided to enhance my replication by making some optimizations.

3.1 Optimizations

When designing the questionnaire, I adhered to the format of the original Shopping Tour experiment. Thus, I adopted the design and, to some extent, the descriptions that were used. Since the experiment was performed in Germany, I translated the descriptions into German. Consequently, I established six product categories, which could also be found in Casasanto (2009):

- ‘Seife’ (= *soap*)
- ‘Schreibtischstuhl’ (= *desk chair*)
- ‘Teppich’ (= *carpet*)
- ‘Planschbecken’ (= *wading pool*)
- ‘Auto’ (= *car*)
- ‘Matratze’ (= *mattress*)

The descriptions of the two possible products were adopted from the original questionnaire and faithfully translated into German. The accuracy of the translations was necessary in order to guarantee comparability with the original experiment.

In addition to the above six product categories, I added six further categories of my own devising, chosen from highly divergent areas of shopping, again following the procedure of Casasanto (2009). However, for these six categories, the competing descriptions contained formulations with different content. The purpose of this modification was explore the influence of handedness on the participants' decisions in cases where the products were clearly qualitatively different. I predicted that these substantive aspects would play the main role in decision making processes, even if handedness might indeed exert some influence on the evaluation of products. Figure 8 exemplifies the newly designed product categories.

aus Alpenmilch fettarm *mit frischen Erdbeeren*	**ERDBEERJOGHURT**	aus frischer Kuhmilch 0,1 Prozent Fettanteil *mit Erdbeeraroma*
Umweltfreundlich reinigt zuverlässig Riecht nach Limetten	**WC-ENTE**	*umweltschädlich* reinigt gründlich duftet nach Zitronen
zergeht auf der Zunge leicht nussige Note *riecht leicht ranzig*	**VOLLMILCH- SCHOKOLADE**	zartschmelzend feines Vanillearoma *duftet stark nach Kakao*

Figure 8: Excerpt of the replication's questionnaire, which shows categories with different content.

These categories are:

- 'Erdbeerjoghurt' (= *strawberry yogurt*)
- 'WC-Ente' (= *toilet cleanser*)
- 'Vollmilch-Schokolade' (= *milk chocolate*)
- 'Kartoffelchips' (= *potato chips*)
- 'Flachbildfernseher' (= *flat-screen TV*)
- 'Mobiltelefon' (= *mobile phone*)

The addition of these products enabled me to add the component *content* to the original Shopping Tour experiment. Since the differences between the two products in each category were not supposed to be completely obvious, distinctive content was only present in one of the three descriptive features.

This is shown in Figure 8, where only the italicized descriptions expressed qualitative differences. The other two descriptive aspects remained semantically almost identical, and were again adopted from the original Shopping Tour experiment in Casasanto (2009). This balance was adopted in the hope that participants would develop only a slight preference towards a certain choice. I expected that the use of multiple distinctive features would influence the participants' choice to such a great extent that other effects, including that of handedness, would have been completely outweighed.

Moreover, the strength of the difference differed from product category to product category. In three of these six items with a qualitative difference, this difference was intended to be quite obvious, whereas in the other half the difference was vaguely perceptible. For instance, the distinguishing features 'mit frischen Erdbeeren' (= *contains fresh strawberries*) and 'mit Erdbeeraroma' (= *contains strawberry flavor*) in the product category 'Erdbeerjoghurt' (= *strawberry yogurt*) – printed in italics in Figure 8 – would not be expected to give rise to a strong tendency towards the former product. It seems logical that the majority of participants would prefer the product 'mit frischen Erdbeeren' to the other possibility, but this is not mandatory; people make their decisions subjectively and on the basis of their own likes and dislikes.

By contrast, in the case of the product category 'WC-Ente' (= *toilet cleanser*), the difference between the distinguishing features is much more pronounced. Assuming the mass of the Western population feel a certain responsibility towards the environment, it can be predicted that the majority of participants should prefer the *environmentally friendly* toilet duck instead of the *polluting* product. The distinguishing features in the category 'Vollmilch-Schokolade' (= *milk chocolate*) should be able to influence the participants even more substantially: here, the participants could choose between a product that smells 'leicht ranzig' (= *slightly rancid*) and another product that 'duftet stark nach Kakao' (= *smells strongly of cocoa*). As a rancid smell is an indication of spoiled food, it can be assumed that all participants who read the questionnaire carefully and had no specific motivation for another choice would choose the chocolate that smells strongly of cocoa. Thus, this product served as a control: it indicated whether the participants read the descriptions carefully or just randomly distributed the crosses and circles on the questionnaire.

As shown in Figure 8, the distinguishing features did not always appear in the first row of the descriptions. This was on the basis that, in everyday life, it is often the things that are mentioned first that have the biggest impact. This principle is very often manifest: for instance, in lists of ingredients it is the main ingredient that is usually mentioned first. Similarly, in movie credits, the principal actors are usually named first. In order to reduce the risk that the participants might apply this principle unconsciously to the descriptions, the positions of the significantly distinguishing features were varied between items.

The ultimate and most important aim of the Shopping Tour replication was to rectify the mismatch between the number of left-handed and right-handed participants in the original study. The effect of handedness could be examined more objectively in a balanced sample, thus bolstering the validity of the results. In order to achieve this, I cancelled out the natural distribution of left-handers and right-handers in the general population by a process of pre-selection. I set out to recruit 100 left-handed participants, aware that, given the distribution of right-handers versus left-handers in the population, it would be relatively easy to then recruit an equal number of right-handed participants.

This natural distribution also constituted the major challenge in recruiting an approximately equal number of right-handed and left-handed participants. Due to this overwhelmingly large number of right-handers in the world, it was impossible to find and test 100 left-handers without particularly searching for them. Finding 100 left-handers by a random recruitment process would also have resulted in the recruitment of 900 right-handers. On the other hand, a call for participation explicitly directed at left-handers, could have led to a distortion of the results, in that it would have revealed that handedness was the object of investigation.

For this reason, the participants were not invited with a notice, but personally asked to participate. A particularly effective approach for this was to recruit at places at which people were writing. Unobtrusive observation of potential participants revealed their handedness. Every potential participant who was observed to write left-handed was asked to fill in the questionnaire. In order to prevent the participants thinking that they were only chosen because of their handedness, the right-handers who accompanied them were also invited to fill out the questionnaire. Thus, this technique also involved the recruitment of some right-handed participants.

This search for left-handers was conducted at the University of Bielefeld and at several locations with mixed clientele. In addition to the canteen, cafeteria, lounges and libraries of the University of Bielefeld, various lottery outlets in Wolfsburg and Bielefeld were visited. Customers of these outlets fill out lottery tickets, so I was able to detect a large number of left-handers merely by observing the shops. I also observed training sessions in table tennis clubs. Not only was it easy to discover left-handers by watching the game, as these players always hold the bat with the left hand, but the proportion of left-handers is also much higher among table tennis players than in the general population (20 to 55 percent; Heinzel, 2008). This is hypothesized to be because people with left-dominant bodies have two advantages in the game: they have a slightly faster response time than right-handers in return plays, and they are accustomed to playing against right-handers (still the majority group), whereas the reverse is not true (Wood & Aggleton, 1989). For this reason, when playing right-handers, left-handers are able to interpret their opponents' movements more effectively than their opponents can interpret their movements.

This multi-faceted search for left-handers should also ensure that the sample of 100 left-handers includes not only academics but also people with lower educational qualifications. This would enable me to investigate the hypothesis that people with different educational levels would prefer different formulations, regardless of the side on which these formulations are positioned. A primary school graduate, for instance, might prefer a soap that *kills germs* rather than an *antibacterial* soap, on the basis that the first term is more firmly established in his active vocabulary than the potentially more difficult foreign word *antibacterial*. By contrast, a high school graduate or university student might be more likely to choose the less frequent word *antibacterial*, since a highly qualified person tends to communicate using a higher language level. For this reason, participants were asked to respond to a multiple-choice question about their educational attainment.

In addition to this, the participants were asked other demographic questions. The principal focus here was on the age of the participants and their performance on the Edinburgh Handedness Test. In this test, the participants had to answer whether they tended to perform various activities such as writing, drawing, throwing objects or tooth-brushing with their right or left hand or if they used both hands interchangeably. The major advantage of using this test was the exact determination of the participants' handedness that it afforded. This contrasts with the procedure of Casasanto (2009), in which the participants were only asked as to their writing hand, which might not correspond to their real handedness. It is possible that some participants only used the right hand for writing tasks and performed all other activities with their left hand, in which case these participants would have been categorized as right-handers for the original Shopping Tour experiment, but clearly and correctly defined as left-handers by the Edinburgh Handedness Test. One reason for this variable preferences in the use of hands could be the once widely practiced *retraining* of left-handed children, who were forced by their parents and teachers to write with their right hands. This retraining might in particular have affected writing but not affected the individuals' preference for the usage of the left hand for other activities involving fine motor control. And this implicit left-handedness could potentially be revealed when answering the questionnaire with a preference for the left.

This is particularly interesting in association with the participants' age. Whereas the re-education of left-handers into *artificial* right-handers is no longer usual, a few decades ago this was a common practice. Therefore, the responses to the Edinburgh Handedness Test are of exceptional importance in the case of elderly participants. If several of these should be found to have been retrained, a very detailed analysis of this group could be useful, since the results from these people might show whether their re-education had led to the establishment of different abstract concepts regarding horizontal positions. The Edinburgh Handedness Test could also detect ambidextrous participants, who act with both sides of their body equally fluently. These people, if detected, should be analysed separately here in order to avoid distorting the results. It is also possible to inquire into whether the degree of handedness of a person leads to a differential impact on mental representations and the evaluation of objects, because the dominance of a certain hand is not always as clearly marked.

3.2 Method

In the replication of the Shopping Tour experiment, the participants were required to accomplish two tasks. The main assignment was to choose one of two products from within each of the twelve categories discussed above. The second task involved answering questions eliciting various demographic data. In addition to the handedness of the participants, which was assessed by the Edinburgh Handedness Test, age and level of education were also surveyed. As previously discussed, this was to determine which of these factors exerted significant influence on the results. The text which introduced the experiment and served to inform the participants about their assignment was acquired from the original experiment and translated into German as follows.

> Stellen Sie sich vor, Sie wollen in einen Supermarkt gehen, um die folgenden Produkte zu kaufen. Zuvor surfen Sie im Internet und informieren sich dort über die Unterschiede der verschiedenen Marken. Schließlich kommen zwei Marken pro Produkt in die engere Wahl. Nun ist es Ihre Aufgabe aufgrund der Produktbeschreibungen zu entscheiden, welchen Artikel Sie kaufen sollten. Für *jede Produktkategorie* gehen Sie bitte folgendermaßen vor: *Kreisen* Sie die Beschreibung der Artikel *ein*, die Sie wahrscheinlich *kaufen* würden.

> *Streichen* Sie diejenigen Artikel *mit einem „X“ durch,* die Sie wahrscheinlich *nicht kaufen* würden.
> (Excerpt from the questionnaire of the replicated experiment)

Although this text represented an accurate translation from the English version and had therefore already been tested by 371 English-speaking participants, a variety of difficulties in comprehension emerged. Despite the detailed description many participants had some problems in understanding the task. A common misconception was that the participants thought they were asked to evaluate the formulations line by line instead of seeing the block of three features as related to each other, since all of these three features served to describe one and the same product. So, taking as an example the toilet cleanser, as shown in Figure 8, these participants attempted to choose between a product which *kills bacteria* and another product that is *antibacterial*, then between a product with a *fresh smell* and one that *smells clean*, and then between a product that is *lime-scented* and one that is *lemon-scented*. Three participants who interpreted the task in this way and were not observed while filling in the questionnaire had to be excluded from the analysis for this reason.

Furthermore, occasionally participants erroneously assumed that they did not have to select a product from each pair, but to select half the products from the questionnaire as a whole. Participants who interpreted the given task in this way chose, for example, both offered soaps, but neglected the category of flat-screen TVs completely. Because of these problems in understanding the written introduction I chose also to give the participants a short verbal introduction. To avoid distorting the experiment, I made sure that each participant had the same information. Thus, every participant began from an identical starting point – and, of course, this starting point was close to the one at which the participants in the original Shopping Tour experiment began, having read the introductory text.

However, this raises the question of why there were no similar problems in understanding documented in the write-up of the original version of the experiment, when this applied the same methodology and largely the same descriptions. As noted in Casasanto (2009), the participants completed the questionnaires without further verbal explanations or additional care. This disparity cannot be attributed to the selection of a wider demographic spread of participants, including those with relatively low educational attainment, in the replication: in fact, most of the difficulties occurred among the student participants, and the majority of lottery players had no problems in understanding the introductory text and in completing the questionnaire.

The recruitment methods described above (section 3.1) enabled me to find 100 left-handers, while keeping the number of right-handers relatively low. The 100 recruited left-handers were accompanied by only 137 right-handers. Thus, the proportion of left-handers was considerably greater in this replication: 40.8% compared to 13.5% in the original Shopping Tour experiment.

Two measures were taken in order to prevent participants discerning the real purpose of the experiment. First, the participants were given a two-page questionnaire. The twelve product categories were printed on the first page. The participants were not permitted to look at the second page of the questionnaire – which concerned demographic data and included the Edinburgh Handedness Test, and could have divulged the likely purpose of the experiment – until they had completed the evaluation of the twelve products. Secondly, after completing the first page, I asked participants verbally whether they had any idea as to the real purpose of the experiment. The majority assumed that this experiment was an attempt from the marketing sector to discover the impact of different types of descriptions on the behavior of potential customers. In this context, some people guessed that the experiment was investigating whether technical or familiar terms were more inviting to potential customers. Similarly, some participants guessed that the experiment was to examine whether foreign words in product descriptions appealed especially to people with higher educational attainment. Another large group of participants thought that the experiment was merely designed to test the patience of the participants, since some of the descriptions were indistinguishable and there was no apparent purpose to asking for a preference. Only one of the participants guessed that the experiment tested the correlation between handedness and the preferred side – but this person thought that, as he said, only for the reason that he was very familiar with the *embodiment* approach. In total, approximately one-third of the participants believed that they had correctly understood the real purpose of the experiment. Furthermore, approximately one third of the participants stated to be able to explain the real purpose of this experiment.

3.3 Results and interpretation

As explained in section 3.1, it was particularly important not to exclude any participants from further analysis without a compelling reason. This principle has been strictly adhered to. Apart from the three subjects who had misunderstood the task, all the remaining 245 subjects were included in the analysis. Using the Edinburgh Handedness Test, a third group besides the right- and left-handers could be found – the ambidextrous people. This group was relatively small: we identified only eight participants who did not have a dominant hand. For this reason, the results from this group will not be considered in full detail in the following analysis.[7] It is interesting that only one out of the eight ambidextrous people stated that they wrote with both the right and the left hand. In the original Shopping Tour (Casasanto 2009), 371 participants were recruited – about a hundred more participants in total than in this replication. Consequently, although it is not surprising that no participants in the original study declared themselves ambidextrous, it is highly likely that there were ambidextrous participants in that study. Recall that, in that experiment, participants only had to disclose which hand they use to write with. As shown in the replication, this activity is not necessarily an indication of a person's real handedness. If ambidextrous participants were in fact present, they were classified incorrectly as members either of the group of left- or of right-handed participants. In addition to the difficulties

[7] The eight ambidextrous people, who participated in the replication of the Shopping Tour, are too few to draw serious conclusions about ambidextrous people in general. If I had treated these eight participants as just as representative as the groups of right-handers and left-handers, this might have led to a distortion in the overall results.

mentioned earlier, this error of classification might also have distorted the results, although it is also possible that the errors balanced out statistically.

In order to guarantee maximal comparability to the original experiment, the first step for the analysis of the newly collected data was the same as that performed by Casasanto (2009). In this step, all participants, who showed no preference for one side, but instead chose six objects on the right and six objects on the left side of the questionnaire, were excluded from the analysis. In addition, the ambidextrous people were also excluded. This was both to ensure that this analysis was comparable to that of the original Shopping Tour experiments (in which no ambidextrous people were present, and only the two groups of right- and left-handers were compared), and because the group of ambidextrous people was too small for their separate analysis to be statistically meaningful.

In this case, this method of analysis led to the exclusion of 60 participants who exhibit no preference for side (see Figure 9), along with 8 ambidextrous participants.

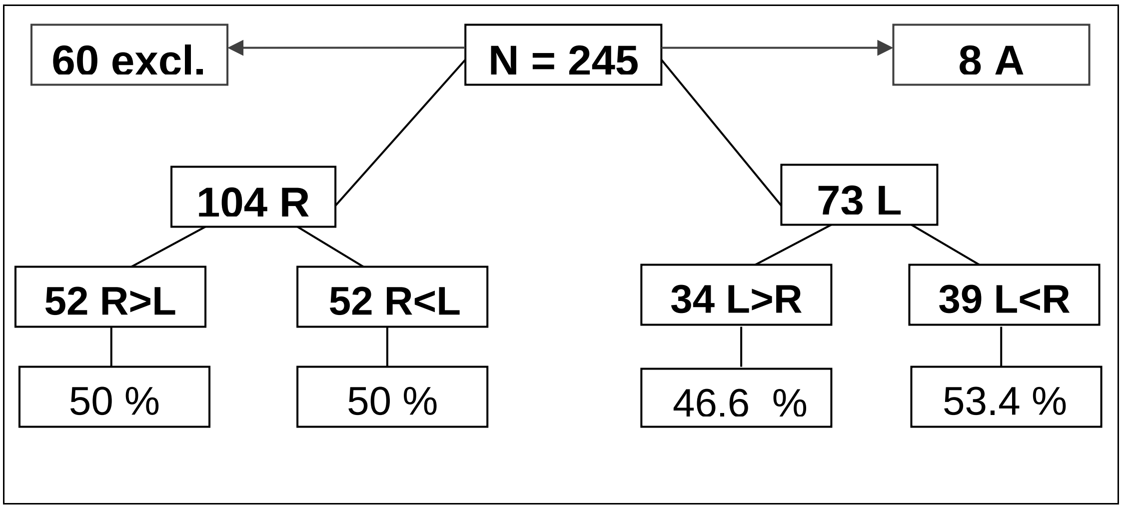

Figure 9: Analysis of the replication based on Casasanto (2009)

The results show that exactly 50 percent of the right-handed participants (52 out of 104 people) showed a tendency towards the right side. However, the other 50% preferred the left side. A similar result emerges from the analysis of the left-handers: 46.6 percent (34 out of 73 people) preferred the left side, while the majority of 53.4 percent (39 people) showed a preference for the right side. There was no statistical difference in the choices of left-and right-handed people ($\chi^2(1, N = 177) = 0.201, p = .654$). This analysis suggests that right-handers and left-handers have answered the questionnaire in a similar way. This interpretation becomes even more likely when we consider the value of Cramer's Phi, which in this case is $\Phi = 0.03$, suggesting an extremely small effect size.

It seems remarkable that this lack of preference emerges even when excluding the group of participants who individually showed no preference, and even without taking into account the intensity of preference. In the original *Shopping Tour* experiment this method of analysis still generated a significant effect. Thus, the participants of the original experiment seem to have exhibited influence of handedness while answering the questionnaire, while the participants in the replication have not.

In a second step, the participants who were previously excluded on account of not exhibiting preference for a particular side were reinstated into the analysis (see Figure 10).

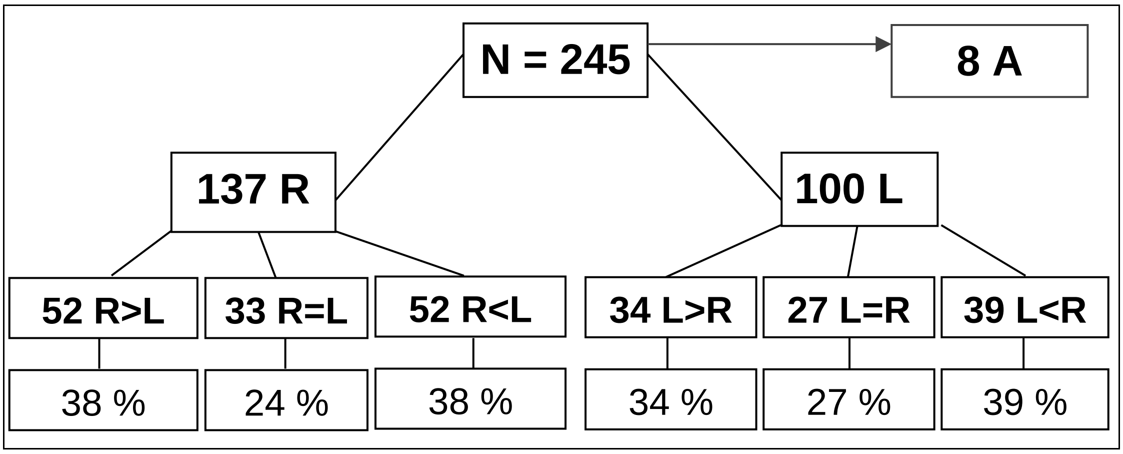

Figure 10: Analysis of the replication including all participants

This procedure also did not reveal a significant effect of handedness on the left- or right-preferences ($\chi^2(2, N = 237) = 0.459, p = .795, \Phi = 0.04$). Compared to the previous analysis, Figure 10 reveals an even more balanced distribution. The groups of participants who preferred the left side, who preferred the right side, and who chose an equal number of products on each side are approximately equally large, each constituting around one-third of the total. On closer inspection, the group of participants with no preference for a particular side is slightly smaller each of the groups who exhibited a preference.

In a next step of the analysis, the strength of the bias is taken into account. As before, the bias can occupy values between -6 to express a strong tendency towards the left and +6 to express a strong tendency towards the right. The uniformity of the previous distribution suggests that the mean values in the groups of the right-handers and left-handers are likely to be near the zero point, in that participants from different handedness groups showed no preference on average. However, the documented distribution would also be compatible with a situation in which some members of each group exhibited a slight bias in one direction, while other members exhibiting a much stronger bias in the other direction. The mean value of these two groups, however, gives reason to believe that the first interpretation is the right one. In the case of the right-handers, this mean value was 0.06, which is nearly coincident with the zero point. This indicates that the right-handed participants, on average, showed no preference for a particular side and chose the same number of objects on each side of the questionnaire ($t(103) = 0.407$, $p = .685$). The same is applicable to the left-handed participants, for whom the mean value was 0.13, also not significantly different from zero ($t(72) = 0.881$, $p = .381$). It is striking, however, that both groups showed a deviation to the right (as signified by the values being positive) even if these deviations were very low. Thus, the left-handed participants on average showed a slight preference for their non-dominant side. Figure 11 depicts the distribution of bias values within both groups.

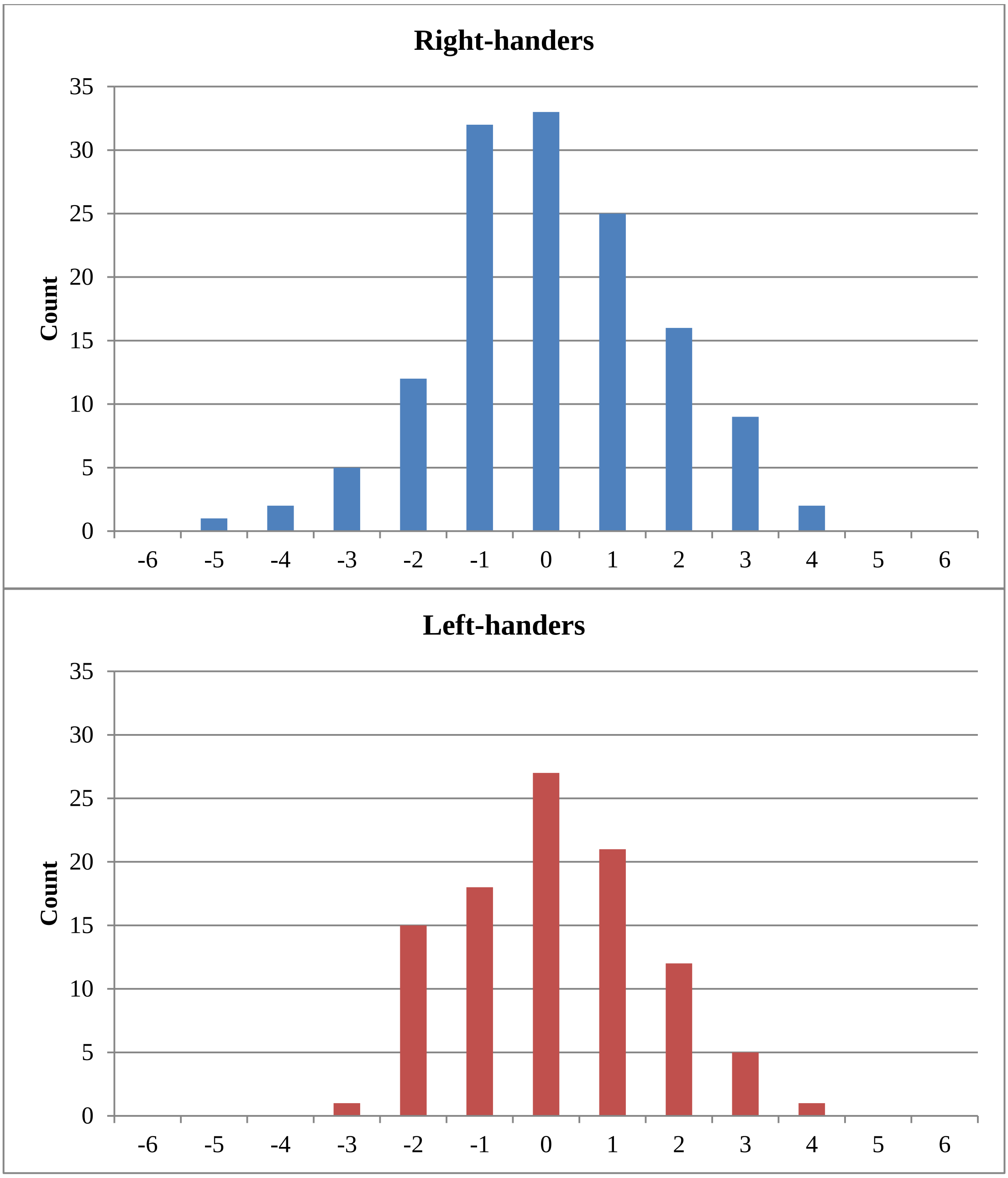

Figure 11: Bias of the group of right-handers and the group of left-handers.

It is particularly striking that both parts of Figure 11 closely resemble each other and are evocative of a Gaussian distribution, as exhibited in the reanalysis of the original Shopping Tour experiment. It is also striking that the most extreme bias values are not attested at all. In the case of the left-handers, no biases of magnitude greater than 4 were obtained. For both groups, an absolute majority of participants exhibited bias values in the range [-2, +2]. Moreover, in both cases, the modal bias value was 0. These findings, augmenting the previously calculated mean values, show more clearly that the participants did not seem to be influenced by their handedness to any significant extent.

In the reanalysis of the original Shopping Tour I proposed to consider participants who exhibited bias of zero or one in magnitude as exhibiting effectively no preference, as was the case for participants who chose the same number of products on the left and the right. In the context of this replication, this would imply that 90 of the 137 right-handers showed no preference for a particular side, and that 66 of the 100 left-handers were likewise within the tolerance range.

Here I will also consider the group of eight ambidextrous people, who were omitted from the preceding analysis. None of the ambidextrous people showed a preference for the left side: two had no preference for a particular side, but six of the eight exhibited a slight preference for the right. Although none of the bias values exceeded 2, this preference for the right side raises questions that cannot be answered on the basis of such a small sample of ambidextrous people. Why did the ambidextrous people have this tendency to prefer the right side? In order to establish this clearly, further experiments with a larger number of ambidextrous people are needed. In the case of this experiment, one might speculate that this result has come about by chance – and is therefore not representative of the population at large. However, there is nevertheless the possibility that at least some of these eight ambidextrous people are re-educated left-handers. This assumption arises from an interesting observation: only two of the eight ambidextrous participants declared that they use their left hand for writing. If one assumes that the majority of ambidextrous people are retrained left-handers, this result is suggestive of a potentially important conclusion: the childhood prohibition against using the left hand for important activities could have resulted in natural left-handers developing at least a slight preference for the right.

In the following analysis, I explore the relations between the choice of objects and demographic data. First, the *Edinburgh Handedness Score* is included in the analysis. This score is obtained by the use of the Edinburgh Handedness Test (Oldfield, 1971) and quantifies the strength of participants' handedness preference. If the Edinburgh Handedness Test[8] yields a figure in the range of -100 to -41, the participant in question is a left-hander. Values between -40 and +40 correspond to ambidextrous people that have no preference for a particular side of their bodies. Values between +41 and +100 refer to right-handers. The greater the magnitude of the value, the more pronounced the handedness preference. Within this replication, we can therefore explore the question of whether people with a stronger handedness also show a greater tendency to their dominant side. If this is the case, participants with an Edinburgh Handedness Score with a large magnitude should also exhibit large values of bias.

The examination of a possible link between the Edinburgh Handedness Score and the bias value shows that there is no significant correlation between the two factors ($r = -0.036$, $p = .571$). That is, there is no apparent correlation between the strength of handedness and the tendency to prefer one particular side. However, this result was predictable, insofar as the uniform distribution in answering the questions gave a first indication for the non-existence of a link. An equally clear result, again showing no appreciable correlation, was obtained for the relation between the participants' choice and their age ($r = 0.028$, $p = .664$). The same is true for the gender of the participants and their bias ($r = 0.083$, $p = .201$) and between their degree of education and their bias ($r = -0.015$, $p = .823$).

The most noticeable difference between the initial Shopping Tour experiment and the replication was the substantive component. The subjects were asked to choose one of the two possible products out of each of the twelve categories. Six of these pairs of products were substantively different. This raises a key question: would the participants – if there is an effect of handedness – continue to make their decisions based on their handedness despite the qualitative differences? It was already shown that no effect of handedness could be found in the general analysis. This suggests that handedness, particularly when deciding between options with different

[8] First of all, I added all crosses made on the left and right side. The selection of the response *no preference* represents a cross on each side. After that, the left crosses are subtracted from the right crosses. The resulting number is then divided by the total number of crosses. The result is multiplied by 100.

content, might play no role. Nevertheless, a closer examination is still useful, particularly for the cases in which the difference in content was small. These cases are of special interest because, when subjects decide unconsciously between superior quality and preferable positioning, handedness might affect their choice.

In the following analysis the eight ambidextrous people were also taken into account, since it can be assumed that ambidextrous people will make their decisions for or against a product based wholly on qualitative differences. Unlike the previous analyses, the consideration of this group would not distort the results in this case.

The results of this analysis were as expected given the results of the previous analysis. Recall that each participant had to choose their favorite object from six categories, which contained descriptions of different content. Contingent on these differences, the outcome of the selection process was, indirectly, determined. This manipulation, however, was very weak in some cases and therefore difficult for the participants to recognize, at least within some of the six categories. Nevertheless, in 72 percent of all cases, the content was taken into account by the participants, who chose the objectively better product. Only in 28 percent of the cases did the participants' decision conflict with expectations. This is shown in Table 3.

		Handedness		
		Ambidextrous	Right	Left
Location of superior product	Left	67 %	70%	73%
	Right	75 %	70 %	76 %
	indifferent	63 %	51 %	51 %

Table 3: Rates at which participants select the superior object, depending on its placement and their handedness. For cases with no substantive difference, rates of selection of the right-hand object are stated.

The first two lines in Table 3 show how often the participants selected the side on which the objectively better product was placed. The last line is used as a comparison. It shows the decisions in those categories which were identical in content. For clarity, this last line only states how many people (classified by handedness) chose the product on the right when there was no difference between the products. This comparison reiterates that the distribution was balanced, and therefore evenly split between the right and the left, only when there was no qualitative difference. This applies to all groups of handedness.

All groups favored about half of the products on the left side and the other half on the right side. The deviation in the case of the ambidextrous people (63% preference for the right) can potentially be explained by the low number of participants, as discussed above. However, when the factor *content* is added, the uniform distribution shifts – and it is obvious that this shift is clearly performed in the direction of the superior content. This *content fidelity* is particularly distinctive in the case of the left-handed participants. However, in those cases in which the better product was placed on the right side, 76 percent of all left-handers identified this as the better product. In the cases in which the better product was placed on the left side, 73 percent of all left-handers chose it. The right-handers identify the superior product around 70 percent of the time, below the average of 72 percent. But these results still demonstrate clearly that the factor *content* strongly influenced their decisions.

The previously made assumptions are brought into focus when we consider how Table 3 would change if the participants were wholly influenced by their handedness. If handedness had such a mighty impact on decision-making processes, the participants would have chosen products placed on their dominant side 100 percent of the time – and they would have done this in spite of the qualitative influences. If this scenario was true, all right-handed participants would have made their decisions against the objectively superior product when this product was placed on the left side. Only if the superior product was placed on the right side would the right-handed participants have chosen it. Only in the case of the ambidextrous people, whose bodies have two dominant sides, would the outcome have been more balanced.

However, Table 3 showed that this is clearly not the case: the distribution is too consistent between participants with different handedness.

So is it the content that affects 100 percent of the participants in their decision? If this was true, participants would always have chosen the objectively better product despite differences in handedness – and not just 72 percent, as the empirical data reveal. Nevertheless, there are reasons to suppose that the content may still be the most important component. First, it has to be accepted that not all participants have read the product descriptions carefully. Minor differences, such as those between a yogurt *with fresh strawberries* and a yogurt *with strawberry flavor*, could easily have been disregarded. Secondly, a choice that conflicts with the objective facts might possibly also be based on the personal preferences of the participants.

As already explained, the participants were closely attended while answering the questionnaire. This allowed the recording of what the participants expressed when they were solving the task. When a qualitative difference was detected and the participants nevertheless chose the objectively inferior product, they sometimes justified this decision verbally. For instance, the participants often refused the environmentally friendly version of the *toilet cleanser*. This was justified by the fact that they had had the experience of environmentally friendly cleaning products which were not able to clean effectively. A similar argument was given by all participants who rejected the *low-radiation mobile phone* in favor of the *radiation-intensive mobile phone*. They argued that the intense radiation devices would ensure better call quality and better service in remote areas and that they only radiate strongly when conditions demand it. Both reasons were often voiced by experts in the surveyed areas. In the case of toilet cleansers it was mainly homemakers and cleaners who expressed the argument stated above, whereas in the case of mobile phones, mechanical engineering students and engineers recognized the potential problem with low radiation devices.

Even personal taste plays a role in choosing an objectively inferior product. In the category *milk chocolate* some participants chose the product that smelled rancid, rejecting the alternative which had, among other properties, *fine* *vanilla flavoring* was rejected. The respective participants justified their choice in classifying the aroma of vanilla as unpalatable. So, the rancid smell would be the lesser of two evils. Similarly, the yogurt with strawberry flavor was preferred over the yogurt with fresh strawberries by some participants, who expressed their subjective dislike of fruit pieces in yogurt, thus explaining their choice of the objectively inferior product.

A similar pattern could be observed in the case of the flat screen TV. In this case, the participants had to choose between a screen size of 37 inches and one of 48 inches. Some of the participants judged the 37-inch TV to be the better one, because they did not know the word *inch* (in German, *Zoll*) as a measurement. The reason for this misunderstanding is that 'Zoll' has two completely different meanings. First, it represents a unit of measure (*inch*). Secondly, it refers to an additional payment that must be made (*duty*). For those who were not familiar with the former meaning, the description seemed to indicate that an additional payment would be necessary in order to buy the device. These participants assumed that the smaller the number in front of the word, the smaller the additional expenditure. One participant mentioned this explicitly: "I do not want to pay duties when buying a TV. But if it is absolutely necessary, then I would pay as little as possible". In sum, although the responses were only congruent with the preferable item in 72 percent of all cases, at least some of the residual cases were those in which the objectively inferior product was subjectively superior in the participants' view.

This effect is further underlined when we look at the effect of qualitative differences in detail. The more obvious the qualitative difference of the products was, the less frequently the participants decided against the objectively better product. This was the case for the three products with extremely divergent descriptions (*toilet cleanser*, *milk chocolate* and *mobile phone*). On average, only 14 percent of the participants in these three product categories refused the objectively better product (toilet cleanser: 18%, milk chocolate: 14%, mobile phone: 11%). When the differences in content were not as pronounced as in these three cases, the rates at which participants chose the objectively inferior product increased: in effect, the decision for or against a particular product became more random.

This can be illustrated in the case of the flat-screen TV. The decision for a certain size of TV is made in accordance with personal taste. The properties and the size of the room in which the TV is to be installed are relevant criteria as well. In this respect, the largest possible screen size is not always sought after. This is reflected in the results. As opposed to the predicted decision, 25 percent of the participants favored the smaller TV. Only two products with a very small difference, *potato chips* and *strawberry yogurt*, were above the average (which was a 28 percent selection rate for objectively inferior products). In the case of the *potato chips* the participants had to decide between an *expensive and high-quality* product and a *reasonable test winner*. It was expected that the majority would judge the *reasonable test winner* to be the better product. The descriptions should imply that both products are very good, but the latter also impresses with a low price and confers the additional advantage that customers can save money by purchasing this product. This marginal difference in content is also reflected in the results. 48 percent of the participants decided against the *reasonable test winner* and preferred a brand product instead of a product that is obviously provided by a discount store. A similar situation could be observed in the case of the product category *strawberry yogurt*. The previously presented arguments against the objectively better product have probably led to the choice of the 52 percent of participants who refused the yogurt *with fresh strawberries*. Consequently, the results observed in product categories with little difference also tend to confirm the hypothesis that the content is the most important factor in the evaluation of objects.

A final question regarding the content is still to be answered: is there a relationship between these demographic data and the tendency to choose the objectively better products? Is it because of the educational attainment, sex or age of the subjects that in 28 percent of all cases the objectively better product was chosen? No correlation could be observed between educational attainment and choices, or between gender and choices. However, the age of the subjects did correlated with the choices made ($F(1) = 5.054$, $p = .025$). The higher the age of the subjects, the more often they chose the objectively better product. One possible interpretation for this phenomenon may lie in the unconventional perspective of younger people. For instance, the older generation is more likely to always choose fresh fruit (such as in the example of the product category *strawberry yogurt*) over strawberry aroma with an uncertain origin. Younger people, due to the increasing *chemicalization* in foods, may be less hostile to artificial aromas in food. Thus, they respond less consistently in the way predicted. A similar argument can be made in the case of the mobile phone radiation. Young people grew up with this medium and may be less concerned about the radiation exposure caused by these devices than is the case for older people. Consequently, it is possible that the correlation between age and content just reflected individual taste and the views of different generations.

3.4 Joint analysis

As summarized in Table 4, the data from the initial Shopping Tour experiment (Casasanto, 2009) exhibited, in the case of the right-handed participants, a slight right preference (when participants with no preference were removed from the analysis). The preference for the left, in the case of the left-handed subjects, however, was more pronounced. In contrast, the replication revealed, in the case of the right-handers, a very weak preference for the right; in the case of the left-handers, there was a slightly more pronounced preference for the right.

	Left-handers	Right-handers	Joint
Original experiment	bias: $t(34) = -1.999$, $p = .054$	bias: $t(236) = 0.483$, $p = .629$	bias: $t(271) = -0.092$, $p = .926$ |L/R|: $\chi^2(1,N=272) = 6.641$, $p = .035$
Replication	bias: $t(72) = 0.881$, $p = .381$	bias: $t(103) = 0.407$, $p = .685$	bias: $t(182) = 1.172$ $p = .243$ |L/R|: $\chi^2(1,N=177) = 0.201$, $p = .654$

Table 4: Previous results from the original experiments and the replication

Given the relatively small samples, especially of left-handers, that are being considered, it is of interest to run an analysis over the pooled data, which should lead to more powerful statistical results. Therefore, it was of great interest to investigate what would happen, if I combined the data of both experiments, the original Shopping Tour and the replication – and thus, evaluate the results of all participants in the same analysis. The group of ambidextrous people was excluded because this group did not appear in the original experiment, and hence the pooled data for this group would be identical to the data already analysed above. Thus, we consider the results from 371 participants in the original experiment and 237 participants in the replication.

As expected, the combination of the two data sets resulted in a shift towards neutral preference. In a first step, as before, we just consider the preference of participants for a particular side, and ignore the extent of their bias. It turns out that there was no significant difference between handedness and the side on which the subjects selected the majority of the objects ($\chi^2(2, N = 608) = 1.494$, $p = .474$). In a second step, the bias values were considered. It was found that subjects on average were very close to zero bias. Thus, there was no significant preference for a particular side. Neither of the two groups showed a significant deviation from the uniform distribution: the right-handed participants revealed an average bias value towards the right side of 0.05

($t(339) = 0.627$, $p = .531$), whereas the left-handed participants exhibited an average left bias of -0.03 ($t(106) = 0.285$, $p = .776$). The lack of an overall effect reflects the fact that the sample of left-handers who exhibited a collective bias in the original Shopping Tour experiment was relatively small.

However, one must note at this point that the two datasets are not completely comparable due to the added “content” component in the replication. As shown earlier, in half of the product categories in the replication, there was one objectively better and one objectively worse product. Thus, the participants were influenced in their choice for these objects. However, the remaining six product categories had, as far as possible, the same contents.

3.5 Discussion

The re-analysis of the Shopping Tour experiment, and the criticism regarding the implementation and analysis of the original work, point in the same direction as the replication and the joint analysis of both data sets. They suggest that no significant relationship exists between the decision for a particular product out of a product category and the side on which the product was displayed. That is, handedness does not seem to influence decision-making processes in this perceptual judgment task. The right-handers and the left-handers in both experiments did not seem to abstract any negative or positive aspects from the sides on which the descriptions of the products were positioned. It is much more likely that they chose one of the given product options primarily on the basis of its properties or apparently at random.

Thus, neither the original Shopping Tour experiment – after closer inspection – nor the modified replication was able to confirm the body-specificity hypothesis. On the contrary, the results from the left-handers in the replication conflict with the claims the *body-specificity hypothesis* makes. More left-handers showed a tendency to the right side than to the left side of the questionnaire. Though this majority is very small and cannot be taken as evidence for a left-handers' bias to the right, it nevertheless reveals that the left-handers were not influenced by the position of the object in the performed perceptual judgment task. In contrast to the claims of Casasanto (2009), a more detailed examination of the original data of the Shopping Tour could not prove a significant effect of handedness on the side which the participants tended to prefer.

3.5.1 English versus German

The Shopping Tour experiment focused on language, to a much greater extent than all other experiments concerning the body-specificity hypothesis. If linguistic metaphors actually arise from mental metaphors, as suggested in Casasanto (2009), the language in which the experiment was implemented would exert a profound influence on the results. In the English language the word *right* is not only a spatial expression, but also a synonym for *justice*. In German, the word 'rechts' (= *right*) expresses only the spatial word *right.* This also applies to the noun 'das Rechte' (= *the right*). All other words including the word 'rechts' or the corresponding noun 'das Rechte' are minimally but still clearly distinct. If somebody wants to thematize *the law* with German expressions, he has to use the word 'das Recht'. In contrast to its origin ('rechts') the *-s* at the end of this word is missing. That is, unlike the English equivalent, a completely new phonological word has evolved.

The similarity of 'rechts' (= *right*) and 'richtig' (= *correct*) is only minimal. However, as discussed previously, in the old German adage 'Er trägt das Herz auf dem rechten Fleck', the phrase 'am rechten Fleck' could be interpreted in two different ways. The adage could mean that this person's heart is located on the right side of his body. But it could also mean that his heart is on the correct side, which makes this person particularly 'big-hearted'. This leads to the assumption that the shift to the currently used 'richtig' has only been caused by language change. Nevertheless, this phrase is nowadays not very frequently used in everyday German. Therefore, the word ‘rechts’ is not likely to be used as a synonym for ‘richtig’. Thus, the slight shift in the results of the original Shopping Tour experiment and the replication could be explained with reference to the language in which the test was performed. However, since the more detailed analysis of the original experiment revealed that no robust handedness effect occurred, this aspect is highly likely to be negligible.

There is another issue concerning cultural influence which merits discussion. It is also possible that the characteristics of the country in which the experiment was implemented has exerted influence over the outcome. Although the original experiment and the replication were both implemented in Western countries, there will inevitably be small differences between the points of view of Americans and Germans. The word *right* occupies only positive implications in the English language, whereas the German ‘rechts’ is – due to the National Socialist past of Germany – strongly negatively connoted. As previously shown, the term ‘rechts’ is always weakly (‘das Recht’) or strongly (‘richtig’) modified, when it is not used as description of a position. Only in one situation does the word ‘rechts’ remain in its original form: this applies to circumstances in which the word is to be understood politically. In the political context, the word can convey two different meanings. In one interpretation, it states that an individual or a party is oriented conservatively. On the other, ‘rechts’ is often used synonymously with *radical right-wing* and evokes mental representations regarding the extremely negatively affected history of Nazi Germany.

In sum, it is possible that the word *right* is not as positively connoted for German participants as it is for American participants. So, this is another possible explanation for the slight differences between the two versions of the Shopping Tour experiment. However, it does not explain why the left-handed participants displayed a slight bias towards the right. In this case, two different forces could have influenced the participants in opposite directions: firstly, the constant exhortations addressed to a left-handed child who is trained to work with the right hand could have led to a strong bias towards the right. Secondly, this effect could then have been weakened by the cultural context, which has taught Germans that ‘rechts’ is bad. If the body-specificity hypothesis is correct, then this would be an appropriate approach to explain the slight discrepancies in the replication. But, as already mentioned, there was no certain difference between the results of both versions of the experiment, which suggests that a detailed search for an explanation would be premature.

3.5.2 The importance of content in decision making processes

The previous section has already touched upon the issue of semantic differences. The replication of the Shopping Tour experiment did not provide any additional insights into how participants choose between qualitatively equal objects, other than that there was no evidence that the handedness of the participants was a critical factor. However, if a fundamental difference between the two selectable objects was recognized, this difference was supposed to be the determining factor in the choice for or against an object.

This became especially clear in comparing objects with strong qualitative differences with those that were only marginally different. In the case of the descriptions with strong substantial differences, the objectively better product was chosen in 72 percent of all cases. However, if this difference conflicted with the subjective taste of the participants, the rate fell, sometimes to below 50 percent. Both findings show how strongly the participants were influenced by the component *content*, which – in contrast to handedness – is a non-negligible factor in every person's decision making processes. If an object is placed on the non-dominant side of the participant, but has significant qualitative benefits, this participant is likely to prefer this objectively superior object instead of the product in the putatively more admired position. Therefore, the component *content* has more influence on the participants than the factor handedness.

A further indication of the importance of content in the evaluation of descriptions lies in the behavior of participants when consciously making choices that do not meet the standard. Virtually every participant felt obliged to justify such unconventional decisions. This shows that the participants recognized the difference in content and knew which product was objectively better. Indeed, the participants not only recognized the objectively better product, but appeared to know that it would actually be their task to choose this product – and that their different choice implicitly violated certain unspoken rules. After all, people in the Western world experience several times a day the need to perceive and internalize substantive information. Whether we are dealing with the listing of ingredients on food packages, the package inserts of drugs or the fine print on the cellphone contract – if we fail to perceive substantive content, we may be vulnerable to health problems or financial hardship.

By contrast, none of the participants displayed any need to justify the choice of a product just because it was positioned on the non-dominant side. This implies that the content is consistently accepted as an aid to decision-making – and that people are also aware of this. It is obvious that the same is not applicable to handedness. It is not conventionally expected that participants will choose an object based on its position. Thus, handedness is used only unconsciously in support of decision making, if it is used at all.

3.5.3 The “right” left-handers and ambidextrous people

As discussed earlier, the majority of the 50 left-handers in the original Shopping Tour experiment showed a preference towards the left (a pattern that was not mirrored in right-handers). After reanalysing the results, this preference turned out to be not that pronounced any more. However, a slight preference was still extant. This phenomenon has been explained on two possible grounds by Casasanto (2009):

> First, asymmetries in perceptuomotor experience may be more salient for left-handers, who are habitually inconvenienced by customs and devices designed for righthanders. More salient perceptuomotor asymmetries could result in stronger associations between actions with

> the dominant hand and experiences with positive emotional valence. Second, culturespecific mental metaphors may be interacting with the bodyspecific left–right spatialization of valence through a blending of three metaphorical mappings. (Casasanto, 2009, p. 362)

However, given the results of the replication, it appears somewhat likely that the apparent preferences of left-handers in the original experiment arose as a matter of chance.After all, compared to the original Shopping Tour experiment in the replication twice as many left-handers were tested. With this number no significant effect occurred. On the contrary, the left-handers even showed on average a minimal preference for the right. How could this be brought in line with the body-specificity hypothesis? These results simply do not seem to be consistent with the claims made in Casasanto (2009), nor do they fit with the explanation that Germans do not link the expression *right* with exclusively positive mental representations (see section 2.2.1).

Similarly, the question arises of why, in all of the experiments proving the body-specificity hypothesis – especially in the Shopping Tour experiment – such a large group of participants acted completely inconsistently with the expectations of Casasanto (2009). If different bodies entail a different perception of the environment, then this principle should apply to a large majority or even to the totality of people. Nevertheless, a large number of participants in all studies concerning the body-specificity hypothesis have contradicted the hypothesis in their actions. How can we interpret the behavior of these people? Why has this supposedly universal body-specificity hypothesis no applicability to such a large number of people (in the replication of the Shopping Tour experiment, even the clear majority of participants)? Does this hypothesis need a detailed elaboration that specifies the extent to which people are influenced by their physical characteristics – and which kind of people are influenced at all?

On this latter point, it is possible that sensitivity to handedness is only cued in those persons who had become aware of the advantages of their dominant side through particular experiences. As I argued earlier, left-handers, for instance, might have gained positive experiences regarding their left side of the body. Nevertheless, they were told or often experienced that their handedness makes them part of a minority, which could make them consciously or unconsciously believe that they are in some way “wrong”. Consequently, if a positive handedness effect occurred, this effect could have been cancelled out by the negative experiences regarding being part of a minority. Another possibility might be that people who experienced a broken arm, or tried to play piano with both hands, could have been particularly sensitized to the positions of objects as positive or negative features of these objects. All these so far unanswerable questions reveal the need for further investigations.

The surprising result that occurred in the case of ambidextrous people could provide some insight into these questions. Six of the eight members of this group had a selection bias to the right. As before, it is quite possible that this pattern arose just by chance, with participants placing their crosses at random. Another explanation, which corresponds to the body-specificity hypothesis, is that the participants experienced repeatedly that the right is linked with the abstract meaning of *good* or at least *better than*. As already indicated, the majority of ambidextrous people might have been re-educated left-handers (Sattler, 1995). These people were perhaps often and successfully told that using the left hand for certain activities such as shaking hands or writing is considered rude or impractical. These warnings may have been heeded by the potentially left-handed child, who later became an ambidextrous person, and represented as a mental concept.

Importantly, this potential concept would have different characteristics from those assumed in Casasanto (2009) as a reason for the *right-is-good*-bias of the right-handers and the *left-is-good*-bias of the left-handers. This concept has nothing in common with the physical experiences which led to the development of abstract concepts concerning horizontal positioning. Rather, this mental concept was adopted from the concepts of people of higher rank, such as parents or teachers. It is obvious that the constant reinforcement of the convention *right is good* in the education of some left-handers could have been able to cause an adoption of this concept in the decision-making processes of these left-handers. This idea has a greater applicability to the ambidextrous people, since in this group the re-education of the right hand as a writing hand was successful. This leads back to the thesis that the body-specificity hypothesis still requires further differentiations. People who have consciously learned to appreciate the dominant side, or people who became used to this *right-is-good* concept in their early childhood, might tend to incorporate this concept into their unconscious decisions.

3.5.4 The missing component

So far one aspect has been unacknowledged. This aspect is the cerebral lateralization of a human's brain, which is normally structured as follows. The left hemisphere processes and produces language and similar functions. The right hemisphere deals with visual-spatial tasks (Levy 1973, Levy & Reid 1978). However, this does not apply to all humans:

> … in 35% - 50% of sinistrals [left-handers] and 1% - 10% of dextrals [right-handers], the right hemisphere is specialized for linguistic skills, and in some unknown fraction of the two handedness groups, verbal and/or spatial abilities are, to varying extents, bilateralized. (Levy, 1978, p. 119)

This reversed lateralization could also be responsible for slightly altered mental representations in this group of people. This hypothesis could be brought in line with the body-specificity hypothesis, which states that people with different physical properties shape different mental concepts of the same reality (Casasanto, 2009). This raises the issue of whether the Shopping Tour experiment should be further extended with reference to this issue in order for us adequately to be able to interpret the resulting data. That is, the recording of handedness alone may not be sufficient to make a statement about whether and how the body-specificity hypothesis applies in this case. The recording of a participant's handedness *and* lateralization experiments probably could have achieved clearer results. Such results could be able to confirm or disprove the body-specificity hypothesis in a more definitive way.

According to Levy and Reid (1978), lateralization can be tested by observing a person’s hand position while writing. This position is an indicator for the lateralization of the brain. If a person’s dominant hand holds a pen in the traditional way, then this person’s brain is probably *normally* lateralized. If his hand holds a pen in the inverted position, in which the hand is above the point of writing and the pen is directed towards the body, then the right hemisphere processes language functions, while the left brain copes with the visual-spatial functions. However, this procedure will not be applied in the experiments reported here, for two reasons. First, very few right-handers are not normally lateralized, and it would therefore be difficult to obtain useful information about the interaction of handedness and lateralization. Secondly, I could not compare the resulting findings with the results of other experiments concerning the body-specificity hypothesis. Since I attached great importance to comparability of the experiments, I implemented the experiments in this dissertation within established paradigms such as those of Casasanto (2009), in which lateralization was not explored.

3.5.5 The limited validity of the body-specificity hypothesis

As discussed earlier, many experiments confirming the body-specificity hypothesis already have been performed. For this reason, the replication of the Shopping Tour experiment alone is simply not sufficient to reject the hypothesis that different bodies experience their environment differently and, consequently, manifest different mental concepts of the same reality (Casasanto, 2009). Nevertheless, it is worth considering what this replication tells us about the limitations of the influence of bodily properties on the mind.

Taking again a closer look at the other experiments proving the applicability of the body-specificity hypothesis, it is clear that all of the experiments can be classified into two different categories – *active placement experiments* and *perceptual judgment experiments* (see section 1.2.4). *Active placement experiments* investigate whether abstract evaluative concepts of objects have an impact on the people positioning these objects. In this type of experiments participants had, for example, to transfer a word or an abstract concept to a position in space. The participants were explicitly asked to place objects with certain positive or negative features on a lateral axis. The results of these active placement experiments revealed participants often placing those objects that they judged to be of superior quality on their dominant side. This tendency to place the *better* object on the side with which they acted more fluently appeared in both children and adults. However, this handedness effect was reduced when the participants had to express their placing decisions for a certain object only verbally. The effect of physical considerations on decision-making processes therefore seems to be closely connected with the motor functions.

The second line of studies testing the body-specificity hypothesis – the *perceptual judgment experiments* – highlighted the influence of placement on the evaluation of a product's quality. To test this impact, only three experiments were performed, which could also be seen as three variations of one and the same experiment (Casasanto, 2009; Casasanto and Henetz, 2012). One of these modifications is the Shopping Tour experiment, as already surveyed in detail. This experiment did not uncover convincing findings. Results that were significant at the .05 level were only achieved after one third of all participants were eliminated and important analytic steps – such as, for instance, the consideration of mean values – were foregone.

This raises the question whether a detailed re-analysis of another experiment, the *Fribble Task*, would similarly suggest the absence of any significant handedness effect. As previously mentioned, Daniel Casasanto confirmed (personal correspondence) that the Shopping Tour and the Fribble Task were not entirely suitable to demonstrate the influence of handedness on the mind. But in what way are these perceptual judgment experiments unsuitable? From my point of view, these two versions of the experiment suggest that the body-specificity hypothesis applies only in those cases in which features have to be transferred to positions. It seems to have much less validity in cases where people are hypothesized to judge objects because of their position.

Consequently, it is possible that in perceptual judgment tasks, as exemplified by the Shopping Tour experiment, no mental connection exists between the positions of objects in the questionnaires and the unconscious preferences of the dominant side. This might be due to the numerous cognitive processes which are activated while viewing pictures or reading product descriptions. In these situations, the *working memory* of the participants is fully stretched. Consequently, the positioning of an object might not be perceived as a significantly positive or negative property of the object, because the person's mind is already busy with other processes, which are – as experience probably teaches – more important for the evaluation (Bruce et al., 1996). Maybe the positioning of an object plays no role, or at least no significant role, in evaluating objects. This issue requires further experimental investigation. These experiments must address the question of whether evaluative spatial concepts can be evoked not only in active placements, but also in perceptual judgment tasks.

4. Experiment II: The *Supermarket Manager*

The re-analysis and the replication of the *Shopping Tour* gave reason to suspect that handedness has no impact, or just a small impact, on decision making processes in *perceptual judgment tasks*. This could be the reason for the existence of the extreme imbalance in the results of these perceptual judgment tasks compared with *active placement experiments* (Casasanto, 2009; Casasanto & Chrysikov, 2011; Casasanto & Henetz, 2012; Casasanto & Jasmin, 2012). Table 1 in section 1.2.4 indicated that a large number of active placement experiments have been implemented in order to test the body-specificity hypothesis, outnumbering the implemented perceptual judgment experiments many times over. Almost all of these active placement experiments were able to furnish evidence in support of the body-specificity hypothesis. These results could be achieved without the exclusion of any groups of participants. It has been indicated that people seem to project abstract properties of objects in their placement decisions, and tend to arrange superior objects close to their dominant side and inferior objects close to their non-dominant side.

However, there might be a reason why only such a small number of perceptual judgment experiments have been implemented, since it seems to be difficult to obtain valid results supporting the body-specificity hypothesis with this type of experiment. Consequently, it can be assumed that these perceptual judgment experiments are simply not suitable to establish the body-specificity hypothesis, because the results suggest that the task of perceptual judgment does not seem to be influenced by a person’s body. These observations further suggest that the results of the original Shopping Tour experiment and the replication could give a hint to potential limitations of the body-specificity hypothesis.

The absence of body-specificity effects in perceptual judgment tasks might indicate that an object’s position is simply not a feature that increases or decreases perceived quality at all. In contrast, the active placement tasks might have achieved these highly significant effects simply because the participants were aware of the superior abilities of their dominant hands and therefore knew that the better product would be much better accessible, if it was placed closer to their dominant side. If this assumption is correct, it should be possible to obtain a highly significant handedness effect from the Shopping Tour by turning this *perceptual judgment task* into an *active placement task*.

As previously described, in the Shopping Tour experiment the participants were confronted with different product categories. They had the task of choosing one of two products out of each category. Each product was presented alongside short descriptions, which were placed in columns to the right and left of each category. In order to test the possible limitations of the body-specificity hypothesis this *Shopping Tour* experiment was reconstrued as an active placement experiment, as follows.

4.1 Method

As in the Shopping Tour replication, the participants for the *Supermarket Manager* experiment were also recruited by preselection at the University of Bielefeld as well as at lottery outlets and table tennis clubs in Wolfsburg and Bielefeld. This strategy once again led to the recruitment of a wide range of people from various different age brands, educated classes and occupation groups, and obtained 100 left-handers and the quite similar number of 120 right-handers. Again, in contrast to the active placement experiments implemented by, for instance, Casasanto (2009), the proportion of left-handed participants in this sample was appreciably higher. Besides these two groups, one participant was classified as ambidextrous.

In this reversed version of the Shopping Tour, the participants were asked to imagine they were the manager of a supermarket standing in front of a supermarket display. Each shelf consisted of three parts. The middle part displayed certain product categories, while the rightmost and leftmost parts of the shelf were empty. The participants were asked to place two objects of the same category into the boxes next to the category names. Thus, in contrast to the Shopping Tour experiment, the participants had to choose a position for both objects belonging to a category, instead of judging one object of each category to be superior and another object to be inferior. By this slight modification, the substance of the Shopping Tour experiment was preserved, but transformed from a perceptual judgment experiment to an active placement experiment. The display that the participants saw is depicted in Figure 12.

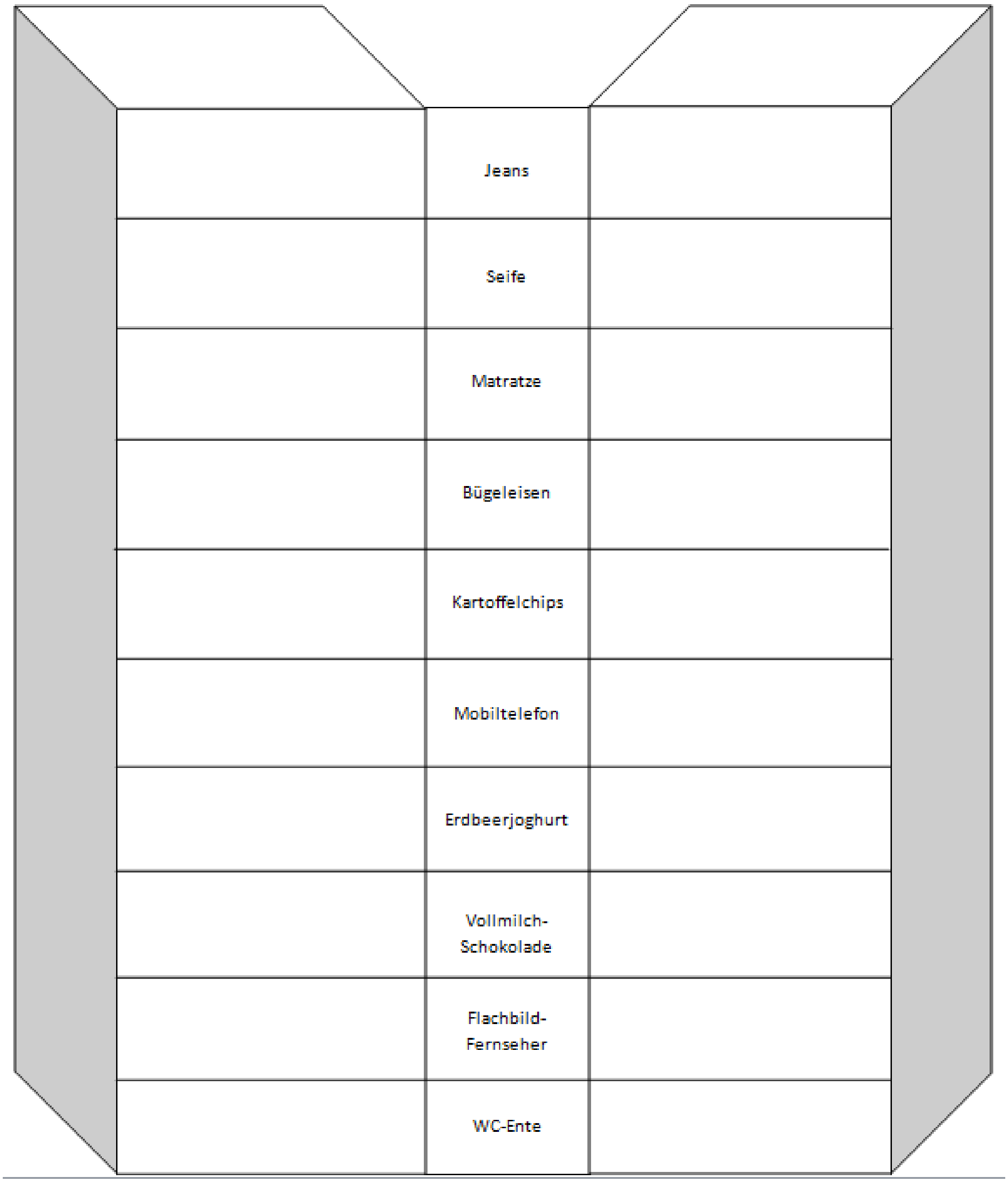

Figure 12: The shelf design of the Supermarket Manager Task

The specific details of the Supermarket Manager task were as follows. As in the Shopping Tour experiment, the participants were required to accomplish two tasks. The main assignment in this case was to position two products on shelves for each of the twelve categories. The second assignment, as before, involved answering questions regarding various demographic data. In addition to the handedness of the participants, which was assessed by the Edinburgh Handedness Test, age, gender and education were also surveyed. As previously discussed, this questionnaire was primarily intended to determine the actual handedness of the participants, since it is highly likely that asking a person only with which hand he tends to write is not sufficient to determine handedness. Besides this, the demographic data were intended to permit investigation into which of these factors exerted significant influence on the decision-making processes. Prior to the questionnaire, the participants each received a laminated sheet of paper depicting the display presented in Figure 12 and a short text that introduced the assignment. This text retained many aspects of the Shopping Tour experiment in order to ensure a high comparability with the perceptual judgment version of this experiment. Given the possibility of certain expressions causing subtle semantic differences, this short text is shown below for clarity.

> Stellen Sie sich vor, Sie sind Supermarkt-Manager. Ihre heutige Aufgabe besteht darin, die Marken verschiedener Produkte in die Regale einzusortieren. Sie erhalten nacheinander zehn Paare von Produkten. Die einzelnen Paare bestehen aus zwei unterschiedlichen Marken eines Produkts (Beispiel: Produkt → Taschentuch; Marken → Tempo versus Kleenex). Entscheiden Sie nun, auf welcher Regalseite die Produkte Ihren Platz finden sollen und platzieren Sie die Marken neben ihren jeweiligen Produktnamen.

This German text expresses – as already mentioned – that the participants were asked to sort different products onto shelves. They received ten product pairs in succession. Every pair consisted of the descriptions of two products within the same category. The participants were then asked to decide which product should be placed on the right and which one should be placed on the left of the depicted shelf. As in the Shopping Tour experiment, the product descriptions consisted of short phrases, and each product was illustrated by three such descriptions. Unlike the Shopping Tour replication, in which six categories contained qualitative differences but the other six did not, the Supermarket Manager task only used pairs consisting of an objectively superior and an objectively inferior product. Again, this difference of quality was only expressed by one of the three descriptions, in order to avoid an exaggerated contrast. An excerpt of these descriptions is shown by Figure 13[9].

aus Alpenmilch fettarm *mit frischen Erdbeeren*	**ERDBEERJOGHURT**	aus frischer Kuhmilch 0,1 Prozent Fettanteil *mit Erdbeeraroma*
trocknet nicht aus *hautfreundlich* Peelingeffekt	**SEIFE**	mit Feuchtigkeitskapseln *kann Brennen verursachen* entfernt Hautschüppchen
Anti-Kalk-System stromsparend Keramik-Sohle	**BÜGELEISEN**	*muss entkalkt werden* geringer Energieverbrauch teflonbeschichtete Sohle

Figure 13: An excerpt of descriptions used in the *Supermarket Manager Task*

The majority of the descriptions used in the Supermarket Manager task have already been used in the Shopping Tour. This applies, for instance, to the item ‘Erdbeerjoghurt’ (= *strawberry yoghurt*). However, the number of product pairs was reduced from twelve to ten. This was to reduce the length of the experiment in order to enable participants to maintain their concentration on the task. In addition, the product categories which were already used in the Shopping Tour and did not contain qualitative differences were modified. This was done, for instance, in the case of the category ‘Seife’ (= *soap*). Other items without qualitative differences were replaced by other categories, as for example in the item ‘Bügeleisen’ (= *flat iron*). I elected to adopt this procedure on the basis that it was important to convey the impression that there were genuinely substantive differences between the products, and the exercise was not merely a trial of patience.

As in the Shopping Tour experiment, the qualitative differences between products varied in strength. In the case of the *flat iron* the participants could choose between a product that *prevents calcareous deposits* and another one that *has to be descaled manually*. This difference is rather weak, insofar as some customers might consider the technology not to be particularly useful. In contrast to this, the item *soap* contained a rather strong substantial

[9] As before the italics in Figure 13 only serve to highlight the descriptions which contained substantial differences. In the experiment, there was no such accentuation.

difference, since the participants had to decide between a product which was *kind to the skin* and a product which *may cause a burning sensation.*

The experiment was carried out in the same chronological order as the Shopping Tour experiment. In the first part of the Supermarket Manager task, the participants saw the display shown in Figure 12 and read the scenario. Then the participants received the product pairs. Each product was represented by a small laminated cards of the same size as the shelves. The participants did not receive the next pair of cards until they had arranged the preceding pair on the shelf.

In the second part of the experiment, the participants received the questionnaire, which was identical to that used in the Shopping Tour. The questionnaire was handed out as soon as the participants finished the sorting task. Again, this sequential order avoided disclosing the reasons for implementing the experiment: no enquiry was made into the participants' handedness until the sorting task had already been completed.

As in the Shopping Tour, the participants were asked whether they could guess the purpose of the experiment. Again, the majority of the participants assumed that this experiment was supposed to investigate purchase patterns, in order to create new marketing strategies. Others theorized that this experiment only served to test the patience of people, in that, despite the qualitative differences between products, the sorting task made no sense from their point of view. Some participants even assumed that the experiment's purpose was to investigate fine motor tasks, since they thought that the cards had to be placed as precisely as possible onto the shelves. Only three subjects guessed that the experiment was designed to test the correlation between handedness and the preferred side. However, two of these subjects were psychology students who had worked on a paper that dealt with handedness.

4.2 Results and interpretation

The Supermarket Manager experiment was implemented in order to enable a point-by-point comparison between an active placement task and a perceptual judgment task. As previously explained, the Supermarket Manager experiment serves as a reversed version of the Shopping Tour experiment. Thus, the analysis was carried out in the same way as the re-analysis of the original *Shopping Tour* experiment and the analysis of the replication. Consequently, the first step of the analysis consisted of an evaluation of responses to indicate the direction of preference, as per the approach of Casasanto (2009) to the original Shopping Tour experiment. This step is shown in Figure 14.

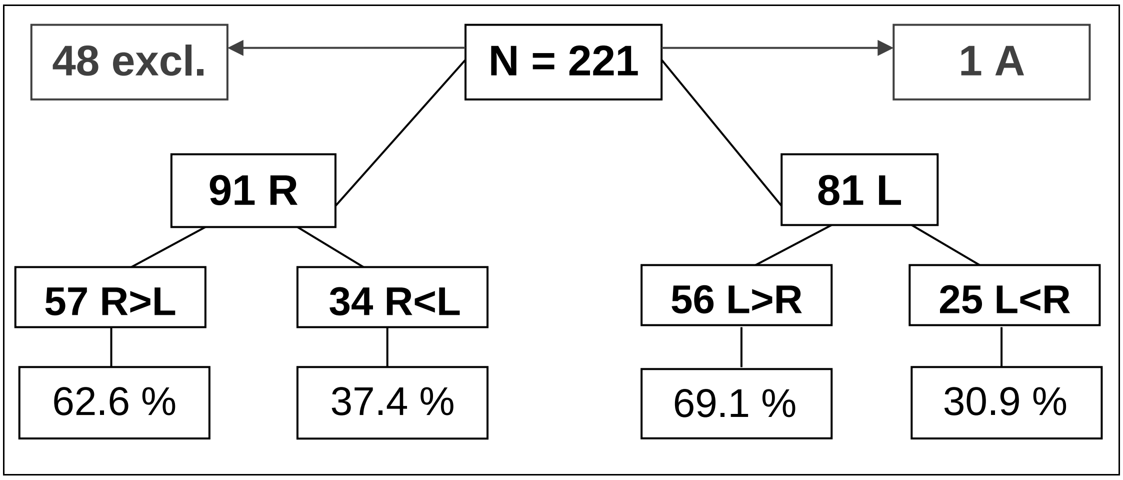

Figure 14: Analysis of the Supermarket Manager task based on the approach of Casasanto (2009).

First, the single ambidextrous respondent was excluded from the analysis. This was planned on the basis of comparability with the original Shopping Tour experiment, in which only two groups, the right-handers and the left-handers, were considered. In any case, as there was only one ambidextrous participant in the Supermarket Manager Task, it was clear that no general conclusions about ambidextrous persons could be drawn on the basis of this sample.

Besides this ambidextrous person, the 48 participants who did not reveal any preference for a particular side were also excluded. These are the participants who placed five of the objectively superior products on the side of the shelf which was closer to their dominant hand and five on the side of the shelf closer to their non-dominant hand. Results from the remaining 172 participants (91 right-handers and 81 left-handers) were included in the analysis. Their preferences are summarized in Figure 14. As predicted, a highly significant majority of these participants preferred the dominant side of the shelf for placing the superior object ($\chi^2(1, N = 172) = 17.343, p < .001$). This applied to 62.6 percent of the right-handers and 69.1 percent of the left-handers. The effect size of $\varphi = 0.32$ can be categorized as *medium*, which represents a much stronger relationship between handedness and placement than could be detected in the case of the Shopping Tour. Consequently, this result is as clear as predicted and as the results of the other active placement experiments testing the body-specificity hypothesis would suggest.

One issue remains to be explored: can this highly significant result be maintained, when all participants are included? This question was answered in the second step of the analysis, which is shown in Figure 15.

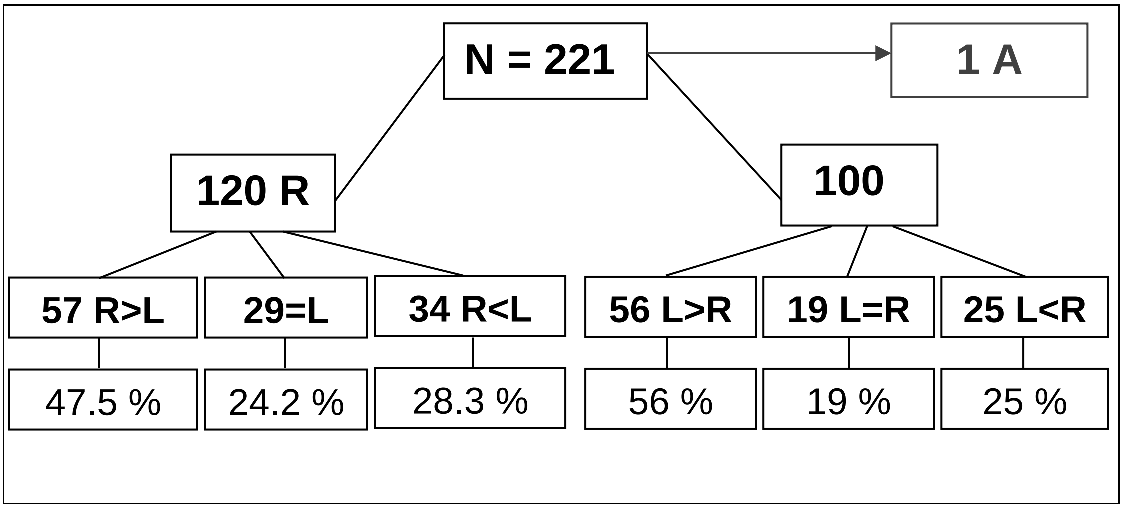

Figure 15: Analysis of the Supermarket Manager task including all participants apart from one ambidextrous person.

In this evaluation, all 120 right-handers and all 100 right-handers were taken into account. Only the one ambidextrous person was removed from the analysis for the reason discussed above. This complete analysis still showed that the left-handers as well as the right-handers revealed highly significant directional preferences in performing the task (χ^2 (2, N = 220) = 18.282, p = .005). For the left-handers, an absolute majority placed the better product on the left side of the shelf. In the case of the right-handers, there was not quite an absolute majority, but 47.5 percent of participants preferred the right side for better products. These results demonstrate that the elimination of the 48 subjects with no preference was not necessary in order to achieve a highly significant effect, as this emerges from both analyses. This is also confirmed by Cramer's Phi ($\varphi = 0.29$), which hardly differed from the value obtained by the analysis suggested in Casasanto (2009).

This significant effect was also supported by the mean values. Due to the smaller number of only ten items per participant, the bias scale in the *Supermarket Manager* experiment ranged only from -5 to +5. Those participants who positioned all ten superior products on the left side were assigned a bias value of -5; those who placed all ten superior products on the right side were assigned a bias value of +5; those who placed five superior products on each side were assigned a bias value of zero. Any integer value between -5 and +5 could be achieved by some distribution of objects on the shelf.

In distinction from the Shopping Tour experiment, the mean values diverged clearly and significantly from the zero point. The right-handers' mean value was 0.98 ($t(119) = 4.224$, $p < .001$); for the left-handers it was -1.17 ($t(99) = -4.291$, $p < .001$). For comparison with the Shopping Tour experiment, in which the bias scale extended from -6 to +6, we should scale these values by a factor of 6/5, which would yield a mean bias value of 1.18 for right-handers and -1.40 for left-handers. These mean values show that, unlike in the Shopping Tour experiment, the participants in the Supermarket Manager task revealed on average a clear preference for their dominant side. However, these mean values do not take into account the distributions of the individual participants: these are depicted in Figure 16.

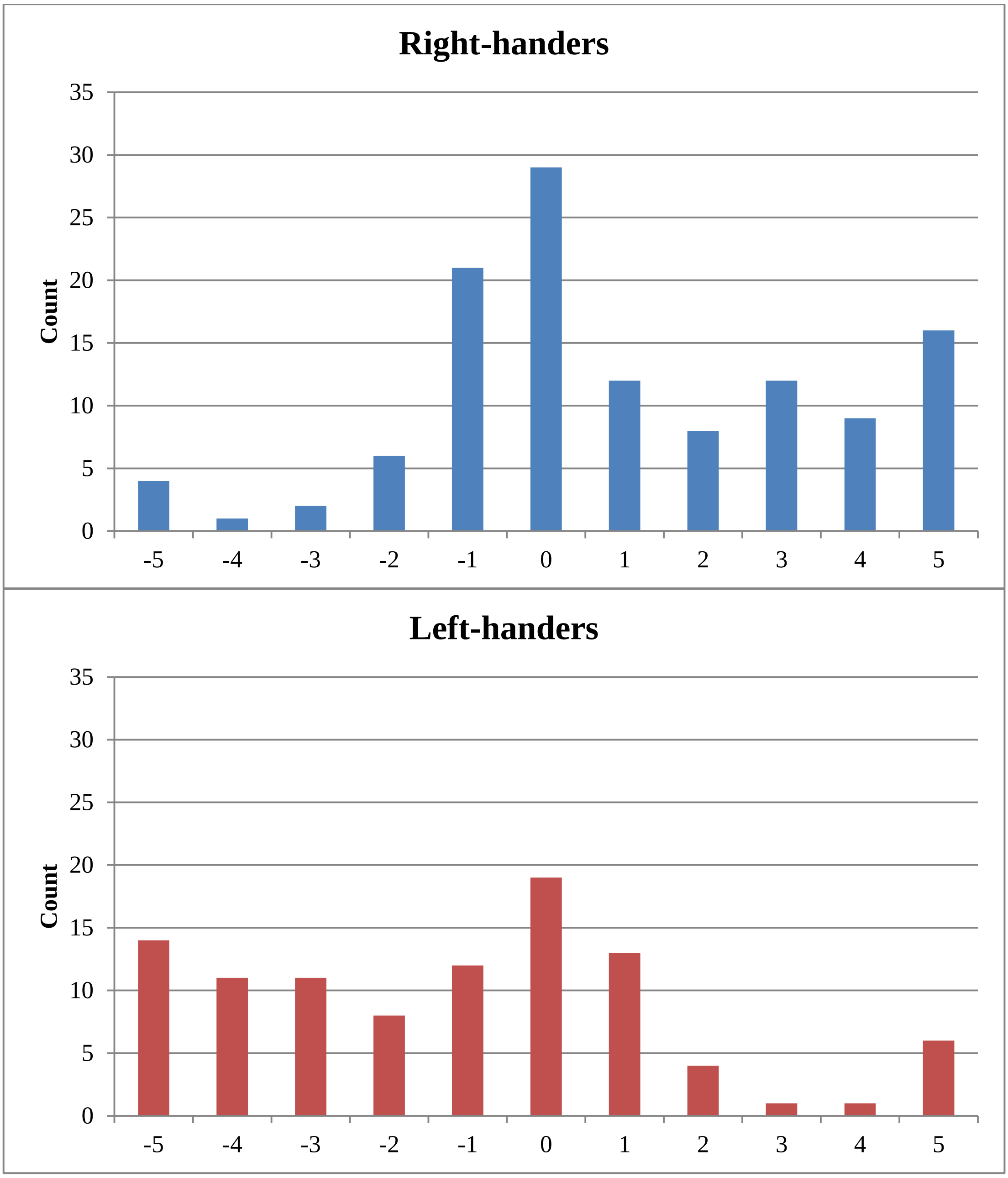

Figure 16: Bias for the group of right-handers and the group of left-handers

Figure 16 stands in marked contrast to Figures 6, 7 and 11, which emerge from the re-analysis of the original Shopping Tour experiment and its replication. In this case, there is little resemblance to a normal distribution. Both the left-handed and right-handed participants had modal bias values of zero, but apart from that, the visual difference between the two graphs is striking. While the largest proportion of right-handed participants is located on the right side of the scale and thus preferred more objects on the right side, a remarkably large majority of left-handers is located on the left side of the scale. Indeed, if one graph was reflected in the y-axis, it would be largely congruent to the other.

This illustration shows graphically what has already been documented by the statistical values. Handedness appears to be the factor that influences the results of both groups in a highly significant way. Consequently, all data gathered in the Supermarket Manager experiment supported the body-specificity hypothesis. A highly significant majority of the participants was affected by their handedness in their placement decision. For clarity, these results are summarized in Table 5.

Left-handers	Right-handers	Joint
bias: $t(99) = -4.291$, $p < .001$	bias: $t(119) = 4.224$, $p < .001$	bias: $t(271) = -0.092$; $p = .926$ |L/R|: $\chi^2(2, N=220) = 6.71$; $p = .035$

Table 5: Summary of the results of the Supermarket Manager Task.

The aim of the Supermarket Manager Task was to create an active placement experiment that contained all the features shared by the active placement experiments of, for instance, Casasanto (2009). One of the most important features of these experiments was the use only of pairs of items which exhibited qualitative differences. In each active placement experiment, the participants could establish which object was supposed to be inferior and which objects was supposed to be superior. The participants became aware of this either through descriptions, by appeal to visually observable characteristics, or through appeal to personal preferences. In the case of the Supermarket Manager experiment, these differences were transmitted through product descriptions, which expressed substantive differences. As in the Shopping Tour replication, these differences were strong in some categories and weak in others.

Unlike in the *Shopping Tour* experiment, every product pair in the Supermarket Manager experiment involved qualitative differences. This restriction also guaranteed maximal comparability with other *active placement experiments*. The application of largely equivalent pairs of products might have compromised the success of the experiment. If, for instance, the first product pair had exhibited no differences, the participants might have concluded that this was applicable to all pairs, and been given the impression that the experiment was merely a test of patience and not meant to be taken seriously. Moreover, within the Supermarket Manager experiment, the use of substantively identical products would not have furnished us with any insights. It would have remained unclear whether the participants were affected by their handedness when placing the objects, because there would have been no better and no worse object, and hence the choice of placement would have told us nothing about positive or negative associations with the right- or left-hand side.

As mentioned, some product pairs exhibited greater differences than others. As in the case of the Shopping Tour replication, I hypothesized that this difference should influence the decisions of the participants. However, the situation in this experiment is slightly different. In the Shopping Tour experiment, the position and content are both independent variables, and a quality judgment is the dependent variable. In the Supermarket Manager experiment, content is the independent variable and position is the dependent variable. It therefore makes no sense to ask whether content or position is more influential to the outcome of this latter experiment. However, it is interesting to consider whether the participants placed the products more frequently on the dominant side the more pronounced the higher quality of the product was.

The initial analysis has shown that the participants tended to place the better object closer to their dominant side of their body. Specifically, in 61 percent of all cases, the participants placed the superior object next to their dominant side. This result is clearly below the value of the replicated Shopping Tour, in which 72 percent of decisions were based on the product quality when the products differed in quality. However, this disparity can be explained by appeal to the detailed observations of the participants that I made during the experiment. Specifically, several participants placed the cards without reading the descriptions accurately. These participants were part of the aforementioned group of people that judged the experiment only to be a test of patience, which did not examine any meaningful questions.

		Handedness	
		Right	left
Preference	right	59.8 %	38.3 %
	left	40.2 %	61.7 %

Table 6: Handedness in relation to the choice of position

Table 6 shows the preferences of the two handedness groups. The top line indicates how often the right-handers (59.8 %) and left-handers (38.3 %) placed the better product on the right side of the shelf; the bottom line shows how often the right-handers (40.2 %) and left-handers (61.7 %) used the left side of the shelf for the better product. It is evident that the majority of both groups often evaluated their dominant side to be more suitable for the better product. In the case of left-handed participants this tendency is a little clearer than in the case of the right-handers.

Looking at the product pairs separately, we can observe interesting variability. Overall, the participants positioned the better product on the dominant side in 61 percent of all case. In some categories, however, this allocation was much clearer. In particular, the left-handers' preference in four product pairs peaks at about 70 percent. One of these was the category *mattress*. In 71 percent of cases, the left-handed participants placed the better product (*with a cotton cover*) on the left side of the shelf, and the inferior mattress (*with a synthetic cover*) on the right. Across left-handers and right-handers, 69.3% of participants placed the *mattress with a cotton cover* on the dominant side. In the case of the category *soap*, the distribution was similarly clear: 69 percent of the left-handers placed the *skin-friendly* soap on the left and the soap that *may cause a burning sensation* on the right. Overall, 63 percent of participants placed the former item on the dominant side. Likewise, in the category *chocolate*, 68% of left-handed participants placed the objectively superior product with a *fine vanilla flavor* on their dominant side and the inferior product that *smells rancid* on the non-dominant side. Across all participants, this value decreased to 64.9% percent. Even in the case of the *LCD TV*, the distribution is especially clear, particularly in the case of the left-handers. As in the *Shopping Tour*, descriptions made reference to a TV with a *48-inch screen* and another TV with a *37-inch screen*. 68 percent of the left-handers placed the larger TV on the left side of the shelf. Considering left- and right-handers together, however, only 60.3 percent of the participants placed the larger and, thus, objectively better TV on the dominant side of the shelves (below the overall average of 61 percent).

These four examples involve categories in which the qualitative differences are large. Those participants who had read the descriptions carefully would normally always judge the objectively better product also to be the subjectively better product. They would not choose a soap that can harm the skin or cause pain; nor, as discussed in the replication of the Shopping Tour experiment, would they choose a food that smelled rancid, as this would normally be a sign that the product was unsafe to eat. The apparent danger emanating from these two products offers an explanation for the distinct distributions. It is highly probable that those participants who placed the cards in an orientation depending on their handedness chose the appropriate positions of the products for this reason. As mentioned in the replication of the Shopping Tour, it is still possible that a few participants still classified the objectively worse product as the subjectively better product for personal reasons, but these cases are likely to be exceptional. By contrast, for products that exhibited relatively small differences, there is a greater likelihood of participants' subjective preferences conflicting with objective advantages. This principle was already apparent in the case of the LCD TV. Certainly, there are people for whom a large TV would be out of keeping with their décor, or unimportant, or distracting. These people might consider the smaller TV to be the better one. Thus, the decision between the two products is much more subjective and less predictable than in the case of the categories with large objective contrasts.

This principle could also be observed to affect behavior in the category *mobile phone*. This item was also used in the replication of the Shopping Tour, and attained comparable results in the Supermarket Manager experiment too. Recall that the participants were presented with descriptions of a mobile phone *with high radiation intensity* and one *with low radiation intensity.* Both the right-handers (57.5 %) and the left-handers (54 %) revealed only a slight tendency to place the objectively better product on the dominant side. However, this result was to be expected after the experiences with this item in the *Shopping Tour* experiment, where quite a few participants had justified a preference for of the objectively worse object. They stated that they would prefer the phone that radiates more strongly, because it has better reception. It is likely that in this experiment, some participants also positioned these items on the basis of this principle. In the case of the product pair *potato chips*, the objectively better object was even less clearly recognizable. Both products were identical, except for the fact that the first product was described as a *reasonable test winner* and the other was called *expensive and of high quality*. Therefore, a difference in preferability was hardly detectable in this category. Only the price functioned as a criterion that distinguished the superior from the inferior product. That being the case, the results obtained with this category in the Supermarket Manager experiment are not surprising: only 59.2 percent of the right-handers and 54 percent of the left-handers placed the objectively better product close to their dominant side of their bodies.

In conclusion, therefore, it can be argued that in the results of the Supermarket Manager experiment as well as of the results of the Shopping Tour replication might not correspond reliably to the actual distribution of body-specific preferences. In 61 percent of all cases, the participants in the *Supermarket Manager* experiment placed the object that was objectively better on their dominant side. However, the rate at which subjectively better items were placed on the dominant side is likely to be higher than this. The objective evaluation of the products does not correspond perfectly and consistently to the subjective evaluation done by the participants for any of the given items. For logistical reasons, most participants performed the placement task simultaneously and in close proximity with others, but often at different speeds. For this reason, I opted not to inquire immediately as to the reason for their placement decisions: otherwise, the other participants could have been influenced in their decisions by the justifications that were given. I only asked them, shortly after finishing the experiment, whether they could guess why they had to perform the task (see section 4.1). Consequently, the placement strategies of the participants remained in their mental "black box". Nevertheless, the highly significant results of the Supermarket Manager experiment enable us to draw quite clear conclusions.

4.3 Discussion

The remarks made in section 3.5.1 regarding the differences in language and – to some extent – in culture, are still applicable for the Supermarket Manager task. Nevertheless, it is striking that this task was able to elicit a significant effect of handedness that is highly comparable with the results gained by the other discussed active placement experiments. Consequently, the influences that resulted from implementing this experiment in Germany turn out to be negligible in the reversed version of the former perceptual judgment experiment.

In addition, the discussion in section 3.5.2 partly applies to the Supermarket Manager task. As in that case, those participants who read the descriptions carefully and did not perform the task completely arbitrarily simply have to have been influenced by the content. There was no other factor which could have had an impact on the participants' behavior: the cards were equally large and each of the two products was given three short descriptions. So the participants' statements gathered in the replication of the Shopping Tour seem also to be relevant to the Supermarket Manager task. They indicate that the objectively superior products were not always subjectively superior.

From this, coupled with the stronger directional bias when the objective differences were larger, one can infer that the proportion of subjectively superior items which have been placed close to the participants' dominant side is appreciably larger than the percentages quoted in section 4.2, which quantify the placement preferences for objectively superior items.

This returns us again to the question of why the participants tended to place the superior object closer to their dominant hand. So far, two possibilities concerning this issue have been discussed: either the participants could have acted arbitrarily or they could have decided based on their handedness. It is still possible that those participants whose behavior deviated from expectations were in fact pursuing completely different strategies (just as it is possible that they judged the objectively superior items to be subjectively superior in the majority of cases).

It is conceivable that the people are influenced in their decision-making processes by their reading direction. Since all participants were German speakers, they are accustomed to reading from left to right on the page. Therefore, it is possible that the participants preferred to place the better product consciously or unconsciously at the left side of the shelf, because they might have thought potential customers would perceive them faster and thus decide to buy them. This theory might explain the left-handers' more pronounced directional preference compared to the right-handers. As discussed above, the left-handed participants tended to place a greater proportion of the objectively better objects close to their dominant side than the right-handed participants did. This group might have been influenced by both the reading direction and their handedness. Nevertheless, the highly significant results of the right-handers suggest that this effect of reading direction is either not applicable, or fails to outweigh handedness preferences, for a large number of participants. So the reading direction hypothesis could indeed be tenable, but can only serve as a potential explanation for the more extreme results obtained from the group of left-handers.

In this experiment, however, the change of the participants' perspective should not be neglected. The participants in the Shopping Tour made decisions that affected only themselves. In the current experiment, they had to slip into the role of a supermarket manager. The participants in the Supermarket Manager task might have been aware of the fact that they do not equip the shelves for themselves, but for potential customers. In this respect, the experiment is analogous to one of the previously described active placement experiments, in which the participants had to adopt a zoo visitor's point of view (Casasanto, 2009). It is entirely possible that the participants incorporated this knowledge into their decisions and did not place the products in the way that would have been preferable for them, but instead had the intention to influence their customers with their placement decisions. As a consequence, the participants could have placed the inferior product intentionally in a more accessible location to the customers in order to increase sales. It is also not unlikely that some participants had knowledge of certain marketing strategies, which could also have influenced their decisions. However, this theory appears to run counter to the clear results towards a significant influence of handedness. The odds are, of course, that a minority of participants pursued exactly this kind of thinking. Consequently, this could be an explanation for those participants who tended to place the better product on the non-dominant side.

5. The Manipulation Specificity Hypothesis

The re-analysis and replication of the Shopping Tour task, the results of the Supermarket Manager task, and the results of all the previously discussed experiments testing the body-specificity hypothesis give a highly homogeneous general impression. The experiments designed as *active placement tasks* achieved highly significant results, whereas the experiments designed as *perceptual judgment tasks* failed to provide supporting evidence for the body-specificity hypothesis. This became especially obvious in comparing the perceptual Shopping Tour task with its active placement analog, the Supermarket Manager task. For the most part, both experiments included identical content. Both dealt with pairs of products presented as short descriptions. Both involved the scenario of being in a supermarket. Only the task that the participants had to perform was different: the participants of the Shopping Tour experiment had to *judge* products, whereas the participants of the Supermarket Manager experiment had to *place* products.

But this modification generated extremely different results. Unlike the Shopping Tour, the Supermarket Manager experiment showed a highly significant effect of handedness on the placement decisions of the participants, which emerged completely effortlessly. In the Shopping Tour – as in other perceptual judgment experiments concerning the body-specificity hypothesis – it turned out to be difficult or impossible to discern a significant effect. Only an unconventional method of analysis could reveal effects which were significant at the .05 level. However, even this small effect could not bear more detailed scrutiny. A hint towards the theory that the body does not influence the mind in perceptual judgment experiments is also provided by the third version of the *Zoo Task* (Casasanto, 2009). This active placement task gave rise to highly significant effects in support of the body-specificity hypothesis, as long as the participants had to express their decisions by drawing. However, the verbal expression of their choice clearly diminished the handedness effect.

This suggests that physical properties only influence decision-making processes if one of the following two conditions is met.

- First, spatial motor activities have to be involved while performing decision-making processes. These motor activities could entail moving an object in order to place it somewhere, or drawing an object.
- Secondly, people have to be explicitly asked to transfer the abstract concepts *good* and *bad* to respectively the right and the left side.

I therefore propose the *manipulation-specificity hypothesis*, which states that the impact of handedness is only relevant in active placement tasks and not in perceptual judgment tasks. Thus, body-specificity is only a determining factor when people have to use their hands actively, in which case the better accessibility of objects serves as a positive criterion. This manipulation-specificity hypothesis is weaker than the body-specificity hypothesis, but it is strongly supported both by the combination of the discussed experiments concerning the body-specificity hypothesis and by the two experiments implemented within the framework of this dissertation.

However, there is still a need for further investigation in order to establish the sphere of influence of this manipulation-specificity hypothesis. It remains unexplained why people tend to place superior objects closer to their dominant side of the body. It is highly likely that people act this way only for reasons of comfort or convenience. But what implications might this have? From my point of view this implies that people are extremely conscious of the limits of their physical abilities and incorporate this knowledge into all decision-making processes involving active placement tasks. Consequently, people do not perceive the placement of objects as positive or negative abstract features of these objects, but simply place better objects in a way that guarantees their optimal accessibility. Thus, people seem to place objects highly rationally and in awareness of the strengths and weaknesses of their body. In order to illustrate this principle, people would not start writing with their non-dominant hand without a compelling reason, since their experiences suggest that this would not lead to acceptable results.

In the following chapter, the claims made by Wilson (2002) will be discussed in detail. The main claim of this paper is that *off-line cognition is body based*. With regard to the previously suggested manipulation-specificity hypothesis, this claim implies that handedness should also influence the ability to simulate objects mentally, and that right-handers and left-handers might tend to solve these mental manipulation tasks in a different way.

6. Mental rotation is embodied

6.1 Wilson's view of embodiment

The majority of *embodiment* proponents provide the perspective that cognitive processes have their origins in the interaction of the body with its environment. "This position actually houses a number of distinct claims, some of which are more controversial than others" (Wilson, 2002, p. 625). Wilson outlines six principal and partially divergent claims: (1) cognition is situated; (2) cognition is time-pressured; (3) we off-load cognitive work onto the environment; (4) the environment is part of the cognitive system; (5) cognition is for action; (6) off-line cognition is body-based. Whereas Wilson endorsed the fourth and the sixth claim, she discovered weaknesses in the first three claims and in the fifth. Thus, these four claims are only predominantly true for the most part – as can be verified if we subject these claims to closer scrutiny.

Of course, it cannot be neglected that a large part of cognition is situated. Face-to-face communications, walking or even cooking require cognitive activities that are situated. But there are also cognitive tasks that are solved in non-situated contexts. Humans are able to imagine places they have never been before and situations they have never experienced before. These cognitive *off-line activities* allow people to remember, plan or daydream. Similar limitations can be found in the second thesis. Time pressure only serves as a limitation and not as an important factor in making cognitive processes work. Time pressure creates a mental obstacle which is described by Wilson (2002) as a *representational bottleneck*. The status of being in a hurry diminishes the ability of people to create a complete mental model of the current situation – thus, people tend to be overwhelmed by the time pressure they are exposed to.

Given the opportunity, we often behave in a decidedly off-line way: stepping back, observing, assessing, planning, and only then taking action. It is far from clear, then, that the human cognitive system has evolved an effective engineering solution for the real-time constraints of the representational bottleneck. Furthermore, many of the activities we engage in in daily life, even many that are clearly situated, do not inherently involve time pressure. Cases include mundane activities such as making sandwiches and paying bills, and more demanding cognitive tasks such as doing crossword puzzles and reading scientific papers. In each of these cases, input from and output to the environment is necessary, but is at the leisure of the cognizer (Wilson, 2002, p. 628).

Furthermore, the claim that people off-load cognitive work on their environment is restricted in its scope. It is obvious that people use their environment to solve certain tasks. For instance, people are likely to move around a room in order to develop better ideas about where to position new furniture. They use their fingers while counting and integrate pen and paper for solving mathematical problems. But off-loading is not the only way for people to circumvent the representational bottleneck. People can also rely on stored representations they had to build when performing similar tasks. Furthermore, Wilson (2002) discusses another restriction of this claim. For instance, counting on one's fingers or solving mathematical problems in writing reduces the complexity of mental processing. Consequently, the cognitive work we have to do is less. However, these activities "are performed in the service of cognitive activity about something else, something not present in the immediate environment" (Wilson, 2002, p. 629). The cognitive processes simply make use of external resources in order to achieve new understanding that may or may not be applied later. This process, which Wilson calls *symbolic off-loading*, can be applied to spatial tasks and helps to establish links between different abstract categories. These categories can be mathematical variables that are expressed in a diagram or gestures that catalyze a person's speech.

The thesis that cognition is solely for action also cannot be maintained in its strongest sense. Of course, action is definitely an important task of cognition, but it is not the only one. It can be shown that certain visual inputs prime certain motor activities such as grasping or reaching for an object.

Nevertheless, the proponents of embodiment go many steps further. Memorizing processes, for instance, have been suggested as constituting “the encoding of patterns of possible physical interaction with a three-dimensional world” (Glenberg, 1997, p.1). Nevertheless, a “representation for representation’s sake” (Wilson, 2002, 632) definitely exists. Looking at human faces, houses or landscapes does not evoke any perceptuomotor responses. The same is true for reading processes. While reading a book, no pattern of possible physical interaction develops.

In general, Wilson advocates for a cognition that is not fixed, but completely flexible. Thus, I can notice a piano in an unfamiliar room, and being a non-musician, I might think of it only as having a bench I can sit on and flat surfaces I can set my drink on. But I can also later call up my knowledge of the piano in a variety of unforeseen circumstances: if I need to make a loud noise to get everyone’s attention; if the door needs to be barricaded against intruders; or if we are caught in a blizzard without power and need to smash up some furniture for fuel. Notice that these novel uses can be derived from a stored representation of the piano. They need not be triggered by direct observation of the piano and its affordances while one is entertaining a new action-based goal (Wilson, 2002, p. 632).

The claim that the environment is part of the cognitive system is rejected by Wilson (2002) in its entirety. Some theorists see cognition in this way: “The forces that drive cognitive activity do not reside solely inside the head of the individual, but instead are distributed across the individual and the situation as they interact” (Wilson, 2002, p. 630). Consequently, cognition should be a unified system consisting of the situated cognizer and the situation this cognizer is in. Of course, there is a link between a person’s action and their environment. But a system requires the properties of its elements to affect the other parts of the system. In this case, Wilson gives the example of a car, in which the spark plugs affect the work of the piston. In contrast to this, “many systems are *open* systems, existing within the context of an environment that can affect and be affected by the system” (Wilson, 2002, p. 630). Thus, these systems receive input from the environment. Another distinction can be made, in the case that systems can be *facultative* and only temporarily existent or *obligate* and effectively permanent. If the situation is part of the cognitive system, the system would emerge and split as often as a person enters a new situation – which happens continuously in everyday life. This is uneconomical. Consequently, cognition needs to be an obligate and open system, which receives permanent input from a person’s environment and adapts itself over and over again to a wide range of situations.

In contrast to the previous five theories, the sixth claim, that off-line cognition is body-based, appeals to Wilson (2002). But, in the history of *embodiment*, this claim has tended to be disregarded. Nevertheless, it is highly likely that abstract cognitive activities make use of sensorimotor functions, which are performed only mentally as sensorimotor simulations. Mental imagery, for instance, does not consist of certain propositions, as the traditional view suggests, but instead uses mental representations that store properties of the environment. Working memory also makes use of sensorimotor simulations. It has “separate storage components for verbal and for visuospatial information, each of which was coded and maintained in something resembling its surface form” (Wilson, 2002, p. 633). Experiments support this theory by revealing that the quality of working memory is worse for words that sound similar or for words that include articulatory suppression.

Implicit memory or automated processes seem to be embodied, too. Compare, for example, a novice driver and an expert driver making a left turn, or a novice juggler and an expert juggler trying to keep three balls in the air. In each case, the degree of control over the details of the behavior is quite poor for the novice, and the phenomenological experience of the situation may be close to chaos. For the expert, by contrast, there is a sense of leisure and clarity, as well as a high degree of behavioral control. These aspects of automatic behavior become less mysterious if we consider the process of automatizing as one of building up internal representations of a situation that contains certain regularities, thus circumventing the representational bottleneck (Wilson, 2002, p. 634).

When people have to solve a problem, they tend to simulate a task mentally. An example of this method of problem-solving is the so-called *Buddhist monk* *problem*. This monk needs one day to climb a mountain, the next day he descends. Is it the case that there is a particular point on the path that the monk passes at precisely the same time on both days? Visualizing this problem facilitates the process of finding a solution. The two days should be mentally depicted on a time bar. The time bar of the first day should be put on the top of the other. Continuing this way, a person can “see” two monks climbing the mountain and meeting each other at a particular position.

6.2 Body based cognition and the Shepard Task

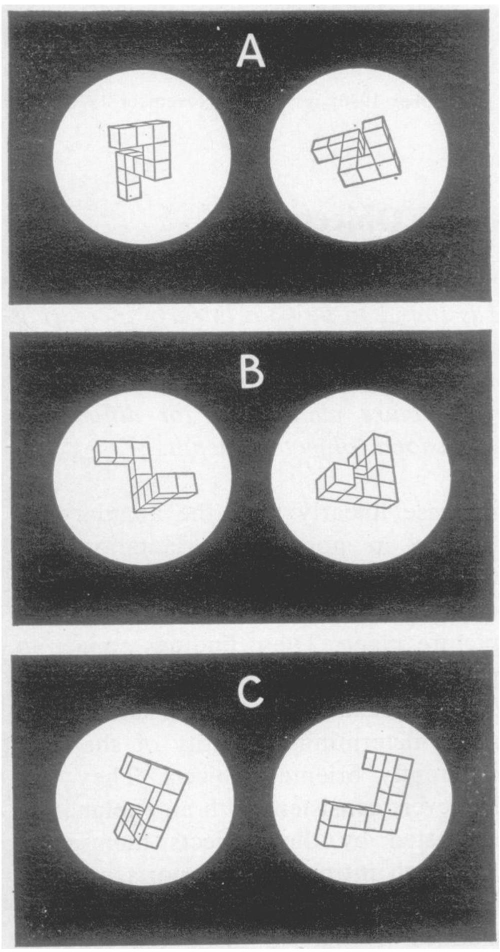

Figure 17: Excerpt of the original Shepard Task.

It is obvious that off-line cognitive activities use sensory and motor resources in many different ways, since the same is observable in activities performed in reality. But, as observed by Wilson (2002), there is still need of further investigation. This also applies to the role of motor simulations, and especially to motor simulations of objects or actions that are imitable “and can be mapped isomorphically onto one’s own body” (Wilson 2002, p. 634). This more distinct evaluation of off-line cognition is particularly important with regard to the manipulation-specificity hypothesis suggested in section 5 which also requires further experiments.

The well-known mental rotation experiment of Shepard and Metzler (1971) gave a first indication that off-line cognition actually is body-based. In this experiment Shepard and Metzler investigated the cognitive processes that are involved in mental imaging and mental manipulation. The participants saw pairs of three-dimensional, asymmetrical drawings that consisted of composed cubes. These picture pairs are shown in Figure 17.

In half of the pairs both drawings could be rotated into congruence with each other. This rotation was implemented either over the x-axis or over the z-axis. In the other half of the pairs of pictures, the objects were incongruent and could not be rotated into congruence again (Shepard & Metzler, 1971). The participants were asked to determine as quickly as possible whether the two drawings were congruent, or whether the drawings were intrinsically different. When detecting identical objects, the participants had to pull a right-hand lever; when detecting incongruent objects, they had to pull a left-hand lever.

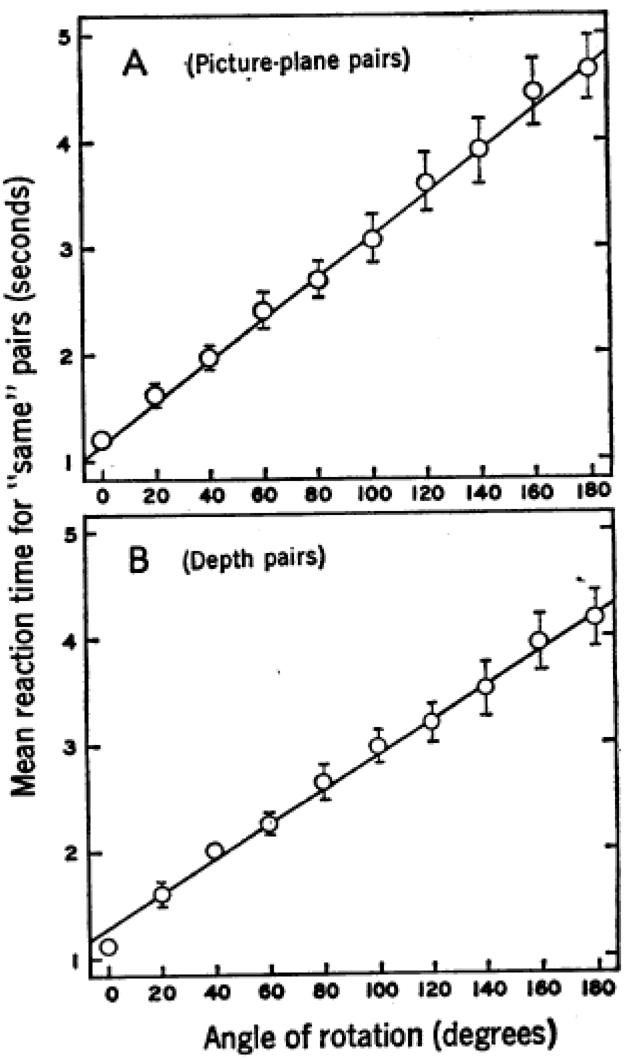

Figure 18: Excerpt of the original Shepard Task.

Shepard and Metzler (1971) developed the theory that people tend to solve such a task by choosing one object per pair and creating a three-dimensional mental image of this object. The participants then come to a decision by rotating this image mentally in order to “see” whether there is a possible rotation that brings this picture into congruence with the other one. Shepard and Metzler depicted the results in diagrams that related the average reaction times for correct responses to the angular difference in the congruent pairs. The upper graph in Figure 18 shows pairs that were rotated on the x-axis, and the lower graph depicts pairs that were rotated on the z-axis. Both diagrams represent the overall mean reaction times as a function of the angular difference in orientation for all correct (right-hand) responses to “same” pairs. “In both cases, reaction time is a strikingly linear function of the angular difference between the two three-dimensional objects portrayed.” (Shepard & Metzler, 1971, p. 703).

The results supported their theory that people create an internal analog of an external rotation (Metzler & Shepard, 1982). It was found that the response time increased linearly with the angular distance between the two objects, and that the plane of rotation made no difference. In effect, the larger the deviation between the objects was, the more difficult the decision was. This supports the hypothesis that the majority of people tend to rotate mental images. Hence, those pairs of drawings that showed a large rotational difference required more cognitive effort, since people had to cover a larger distance mentally in order to bring both objects into correspondence with each other. A difference between the rotation on the x-axis and the z-axis were not detectable. Consequently, it is highly likely that the same strategy was used in both rotation types.

Furthermore, the participants were instructed to express what strategy they had used to establish the (in)congruence of objects. Shepard and Metzler stated that all participants claimed “that to make the required comparison they first had to imagine one object as rotated into the same orientation as the other and that they could carry out this ‘mental rotation’ at no greater than a certain limiting rate” (Shepard & Metzler, 1971, p. 701). The detected positive linear correlation between the reaction time and the angle between the two depicted objects seems to confirm the subjective assessments of the participants. The greater the distance, the more time was needed for this mental rotation. Thus, the mental rotation appears to be analogous to a real rotation. Logically, it takes more time to rotate an object for instance by an angle of 200 degrees instead of only 20 degrees, if we are limited as to the speed at which we can move the object. This conformed with the participants' subjective experience.

But could the results of this one experiment really be interpreted as evidence that people tend to solve spatial problems by mental simulation? Shepard and Metzler (1971, p. 703) stated that "tentatively, [the majority] of these reaction times may represent some such process as "mental rotation" itself, rather than a preliminary process of preparation or search". But the authors also admitted that further research was needed in order to draw broader conclusions. The external validity of this mental rotation theory, for instance, was investigated by Metzler and Shepard (1982, p.71), among others. Their discussion calls to mind Wilson's claim (2002) that off-line cognition is body-based:

> The analog operation that we are specifically considering, viz., "mental rotation", seems to play a central role in tasks ranging from the relatively mundane and concrete one of planning the arrangement of furniture in a room, to the relatively more intellectual and abstract ones of solving problems in geometry, engineering design, or stereochemistry.

It was not only Shepard and Metzler who investigated this topic further. On the contrary, the experiment ignited an explosion of work in this area. So far, more than one thousand articles concerning "mental rotation" have been published[10]. The majority of mental rotation experiments have been based on three-dimensional stimuli, similar to those used in the original Shepard Task (1971). As previously described, these stimuli consisted of ten cubes which were linked with each other in different ways. Part of the motivation for this vast quantity of work was criticism that arose especially because of

[10] This figure has been obtained from the "PsycInfo" database.

Shepard's strong claim of internal representation and his so-called "second order isomorphism" that existed between drawing and image (Shepard, 1975; Shepard & Chipman, 1970; Shepard, 1984). Hochberg & Gellman (1977) or Yuille & Steiger (1983), for example, doubted whether these drawings were rotated by the participants as a whole and posited that the participants simply compared single pieces of one drawing with those in the potential equivalents. Others even questioned whether the observed effect could be explained with imagery (Gibson, 1974). In his paper Gibson objects to the whole idea of mental images (p.42): "We certainly do not summon up pictures inside our head for they would have to be looked at by a little man in the head. (…) Moreover, the little man would have eyes in *his* head to see with and then a still littler man and so *ad infinitum."*

Shepard (1984) replied to these critics that mental imaging is, like perceptual processes, indeed realized mentally by physical procedures. However, there is no need to have a detailed knowledge about these processes in order to examine the phenomenon of imaging. Of course, people perceive or imagine external objects, but these objects need not to be present or even existent. In experiments conducted with Podgorny (1978, 1983), Shepard was able to support this argument. The participants had to look at a square grid, and were given a perceptual task and an imagination task. In the first condition, the participants had to perceive the shaded squares forming an object. In a second condition, there were no shaded squares anymore, but the participants had to imagine they still were visible. Then, in both conditions, probe dots were depicted on the screen and the participants had to judge whether these dots were placed in the same area that had been occupied by the shown or imagined objects. The reaction times were highly dependent on the position of the dots – the closer the dot was placed to the previously perceived or imagined object, the more time was needed to give an answer. Furthermore, these reaction times indicated that the objects were processed in the same way regardless of the condition (i.e., whether they were real or imagined).

Shepard (1984) argues that "by acknowledging that perceiving and imagining – as well as remembering, planning, thinking, dreaming, and hallucinating – do correspond to brain processes, we at least open the door to possible connections with evolutionary biology, clinical neurology, and artificial intelligence." (p.421). This challenged the competing argument that the linear function of reaction time in the Shepard Task only arose because of the necessity of making more eye movements between the two drawings in order to judge their congruence. The larger the rotation level, the more different these pictures seemed to be. Consequently, the possibility had been mooted that more different pictures required more gazes in order to be captured in their full complexity (Just & Carpenter, 1976).

Many scientists, as well as Shepard (1982), concentrated on variations or simplifications of the original 1971 Shepard Task of 1971. One of these simplifications was implemented by Steven G. Vandenberg and Allan R. Kuse (1978). The procedure was the same as that of Shepard and Metzler (1971), but the shown drawings displayed a significant difference. Since Shepard and Metzler were able to show that people behaved similarly in the mental rotation within both planes, the experiment was conducted on two-dimensional rotations only. Referring to the original Shepard Task, the presented stimuli were either incongruent or could be rotated into congruence. Kuse and Vandenberg's study achieved results similar to those of Shepard and Metzler (1971). Furthermore, Kuse and Vandenberg (1978) discovered a significant gender-related difference (male subjects were slightly faster in making their decisions than women) in the mental rotation strategies. This could be taken to correspond to the predictions of the body-specificity hypothesis (Casasanto, 2009), which claims that people with different bodies develop different mental concepts of the same objects.

Another successful replication of the Shepard Task for two-dimensional rotation was implemented by Kirsh and Maglio (1994). Their Tetris experiment supported the theory that participants solve the task of placing the falling objects in the most space-saving way possible by rotation – and not just by mental rotation. If possible, participants also tend to rotate the objects physically. In the Tetris experiment, people rotated the objects on the screen to optimize and accelerate the decision-making process. If the stimuli were not able to be rotated, the participants used to turn their heads to discover a possible congruence between the retinal image of one picture and the memory trace of the second one.

Many experiments completely broke away from the cube-based structure of the stimuli and nevertheless achieved similar results to those of the original Shepard Task. For example, Cooper (1975, 1976) conducted experiments in which complex irregular polygons had to be rotated. Her results also exhibited a linear dependency between reaction time and rotation level. In some of these experiments, Cooper asked her participants explicitly to use mental rotation in order to solve the task. Although the participants used this strategy consciously, the results were still the same. On the one hand, this procedure could support the thesis that mental rotation is always the preferred strategy to solve tasks of this kind. On the other hand, opponents of this theory could argue that the participants were influenced by the instruction and only “produced” those results they thought the experimenter wanted to obtain. However, given the overwhelmingly large number of replications that have since been implemented, the possibility for a simple distortion by the instruction is quite low. On the contrary, Cooper’s experiments put the theory of mental rotation to the test – and succeeded in demonstrating its strength and external validity.

The development of neuroimaging techniques in the 1990s enabled psychologists to discover the brain activities involved in mental rotation processes. For instance, Cohen et al. (1996) succeeded in showing through fMRI a significant change in the blood flow of certain brain areas, while participants performed the Shepard Task – and they detected a premotor activation, which is typical for physical manipulation of objects. “These data are consistent with the hypothesis that mental rotation engages cortical areas involved in tracking moving objects and encoding spatial relations, as well as the more general understanding that mental imagery engages the same, or similar, neural imagery as direct perception” (Cohen et al., 1996, p. 89).

Modern mental rotation tasks have continued to move away from the use of simple stimuli such as cube drawings. In such tasks, the participants often have to rotate hands (Parsons et al., 1995) or whole bodies (Amorim, Isableu & Jarraya, 2006) in order to activate egocentric motor strategies. Many studies, such as Bonda et al. (1995), have shown that the premotor area, as well as the primary motor cortex, is involved in mental rotation tasks. These areas are also activated when subjects are asked to rotate objects physically. This experiment entailed doing a task that involved the mental rotation of the subject's hand and a control task that did not. Regional cerebral blood flow was measured by positron emission tomography (PET). Similar results were found by Parsons et al. (1995), who showed subjects pictures of hands that should be categorized as left and right hand. PET again revealed that the same areas were activated that are involved in motor control processes.

Especially in the recent past, the immediate influence of the body on the results of the Shepard Task has come to be in the focus of mental rotation research. Ionta and Blanke (2009) concentrated on the effects of certain hand postures on the mental rotation of right or left hands and feet. The participants were asked to place their right hand on their right knee and their left hand behind their back – in a second part of this study the hand postures were reversed. In the case of the right-handed participants this manipulation had an influence on the response times for laterality judgments. Interestingly, these reaction times only increased when this group of people held their right hands behind the back while developing judgments about pictures of right hands. An effect for depicted left hands or feet could not be observed. The left-handed participants seemed to be unaffected by the change of hand posture. So, in the case of the right-handers, the power of judgment weakened only for those limbs which were manipulated by the change of posture.

The investigation of the influence of artistic abilities on mental rotation has also revealed effects. Pietsch and Jansen (2012) showed that people with outstanding athletic or musical abilities tend to develop superior mental rotation skills. Sport students achieved significantly faster reaction times in mental rotation tasks than math or education students. Thus, mental rotation seems to be more closely linked to the body than to logical reasoning. Again, it was shown that male participants were faster than female participants. The much more pronounced spatial awareness of athletes – including recreational athletes – was also demonstrated by Moreau et al. (2012). In this experiment the subjects had to deal with a mental rotation task before and after a workout in two different types of sport. After the training, the participants achieved better results than they did in the test before. Consequently, these results point to the possibility of optimizing visual thinking by physical training.

6.3 The influence of handedness on mental rotation tasks

The previous section discussed mental rotation research from the past four decades. The basis of all these experiments is the Shepard Task implemented in 1971. However, mental rotation experiments did not merely confirm the results that Shepard and Metzler discovered. So far, numerous issues have been investigated using this methodology. Gender differences were examined as well as the influence of athletic abilities and the different rotation of limbs and objects. These results have been supported by imaging techniques.

So, the main claim of mental rotation has been proved in many respects. As already indicated, the main message is that merely imagining a rotation corresponds closely to a physically performed rotation. Thus, imagination and perception seem to be similar processes. This idea indeed captures the essence of *embodiment*, which emphasizes the interaction of body and mind (Gallagher, 2005). The nature mental rotation fits especially with the aspect of embodiment that was highlighted by Wilson (2002) as the most important one – that off-line cognition is body-based. The experiment of Ionta and Blake (2009) indicated how powerful the influence of a person’s body can be on off-line cognition processes such as mental rotation. Furthermore, Ionta and Blake explored the difference of this influence on the mental rotation processes of right-handers and left-handers. While the right-handers were influenced in their mental rotation ability by a change in arm position, the left-handers were completely unaffected by this manipulation. This fact again accords with the body-specificity hypothesis (Casasanto, 2009), which claims that people with different bodies interact with their environment in different ways and develop different mental concepts.

This claim leads us to consider that a large number of a person's mental concepts are established by mental simulations of physical experiences. As this dissertation has shown, decision-making processes in perceptual judgment tasks are not significantly influenced by the properties of a person's body. Nevertheless, different bodies definitely have an impact on a person's mental processes, especially when these processes involve physical or simulated activity. This is the essence of the previously developed *manipulation-specificity hypothesis*. Of course, this dissertation, as well as the research conducted with regard to the body-specificity hypothesis, has primarily focused on abstract mental concepts. These principles lead us to ask: if the manipulation of objects affects the abstract evaluation of these objects, is it not correspondingly likely that physical characteristics also impact upon our mental manipulation abilities?

As seen in Ionta and Blake (2009), the Shepard Task might be an appropriate means by which to investigate the influence of handedness on mental rotation processes. The physical manipulation of arm posture has an impact on a right-hander's mental rotation ability. These results call for further development. Due to the fact that *off-line cognition is body-based* (Wilson, 2002), linked with the claims of the manipulation-specificity hypothesis, it should be possible to execute this manipulation not just physically but even purely mentally. That is, through a replication of the Shepard Task, we can show whether left- and right-handed people are also equipped with a mental right hand and a mental left hand. Furthermore, this task might be able to answer several questions. Do left-handers and right-handers – without physical manipulation – rotate the depicted cube structures mentally in a different way? Do right-handed people prefer the rotation of the picture shown on the right side of the screen? And what happens if these right-handers are forced to rotate the left-sided object mentally?

6.4 The differences between right- and left-handers

First, it is necessary to discuss the differences between right- and left-handers. What distinguishes these two groups of people apart from the fact that they prefer a different side of their body for the execution of fine motor skills? The previous chapters only touched upon this question, but here we must examine it more closely. First, the development of handedness can be regarded as an evolutionary development. Widerman et al. (2011) suggested thinking of the higher development of one side of the body as an opportunity for the other side of the body. Due to the existence of handedness, children do not have to train both parts of their bodies in the same way. They implicitly know that one side of the body is well-suited to perform fine motor tasks, whereas the other side is supposed to specialize in different responsibilities.

Of course, the lateralization of brain function (Toga & Thompson, 2003) is important in this context. Findings from studies on the lateralization of the brain show that the left hemisphere is primarily responsible for motor control of the right side of the body and the right hemisphere is primarily responsible for the left side of the body. The dominant hemisphere is the one which processes language, which is the left hemisphere in 95 percent of right-handers, but the right hemisphere in 70 percent of left-handers. There is thus a strong correlation between the dominant hemisphere and handedness. Nevertheless, there is no clear regularity in the connection of handedness and lateralization (Young et al., 2008). Indeed, Oliveira et al., 2010 succeeded in changing a person’s handedness temporarily by stimulating the motor cortex with magnetic pulses.

Consistently in all investigable cultures and in populations of apes the dominance of right-handedness is striking. Interestingly, a consistent regularity seems to be present: the higher the proportion of right-handers, the higher the development of the culture (Previc, 1991). It seems to be reasonable, on the grounds of division of labor, that the two parts of a body do not need to have the same abilities. However, no valid explanation for the predominance of right-handers has yet been found.

This lack of an explanation is especially keenly felt when we consider the advantages that each form of handedness can confer, an issue that has been widely explored in the last decade. Left-handers seem to have a more highly developed ability to solve visual-spatial tasks and to imagine spatial arrangements (Santrock, 2008). This hypothesis not only explains the experimental results obtained by Ionta and Blake (2009), but in a wider sense could be seen as a reason for the strikingly large number of left-handers in the occupational groups of mathematicians, architects, artists and musicians, as Santrock noted. He also notes that 20 percent of the group achieving a top score on the Scholastic Apitude Test (SAT) was left-handed. This proportion significantly exceeds the proportion of left-handers in the Western world in general. Therefore, this test could be an indication of a higher IQ level in left-handers. Judge and Stirling (2003) demonstrated that left-handers exhibit a significantly superior coordination of their left and their right hand. The performance difference between a left-hander’s hands is not as big as in the case of right-handers. Thus, left-handers are more flexible and achieve better results in tasks in which both hands must exhibit fine motor control. This observation may be explained by the fact that left-handers have to come to an accommodation with the right-handers’ world they live in. As previously mentioned, artifacts like scissors and even door handles are built for the purposes of right-handers. So, in the case of the left-handers, higher flexibility is necessary to succeed in everyday situations.

Widerman et al. (2011) link left-handers’ better skills in spatial imagination and their greater flexibility with the outstandingly large number of left-handers in certain sports. However, this particularly concerns those sports in which one interacts with an opponent, such as table tennis, tennis, judo and fencing. Recall that left-handers make up only ten percent of the population in the Western world. While it is commonplace for left-handers to compete against right-handers, right-handers are – due to a lack of experience in playing against left-handers – clearly at a disadvantage (Heinzel, 2008).

But being a left-hander does not merely confer benefits. Initial studies show that left-handers have more difficulties in reading and in phonology (Santrock, 2008). The differences between right-handers and left-handers also extend to health issues. Although left-handers have a lower risk of suffering from arthritis, they lag behind right-handers in their physical development. On average, left-handers are smaller, weigh less, have a shorter life expectancy, reach puberty later and are more likely to suffer from neurological and immunological diseases (Widerman et al., 2011).

7. Experiment III: The extended *Shepard Task*

7.1 Method

The terms *left-handers* and *right-handers* suggest that the only difference between these two groups concerns the hand that is better at performing fine motor tasks. However, the previous chapter and the first two experiments of this dissertation demonstrated that these differences are much more extensive. The outside influences of a world made for right-handers make left-handers more flexible in using their hands. Left-handers often have to solve tasks with their right hands because only right-hander specific tools are available. It is highly likely that this issue is also responsible for the better spatial imagination of left-handers. Thus, the differences between the two groups of handedness are not merely reducible to physical properties, but also influence mental processes in many respects.

As previously mentioned, Ionta and Blake (2009) demonstrated that right-handers are more susceptible to interference than left-handers – a physical manipulation also manipulated their mental abilities. This shows once again that the thinking of both left-handers and right-handers can be influenced by their physical differences. This is not only a confirmation of Wilson's (2002) view that *off-line cognition is body-based*, but raises further questions. What happens if there are no external influences? Do right-handed and left-handed people still perform mental rotation differently? Do left-handers and right-handers even use "mental right and left hands" to reconstruct the rotation?

In the case of the Shepard Task one certain idea suggests itself. Shepard and Metzler (1971) had claimed that in mental rotation people rotate only one of the two figures mentally, while the other remains mentally fixed as a reference model. However, it has never been tested which figure left-handers and right-handers prefer to turn. On the basis of the previously achieved results with reference to differences evoked by handedness, it could be hypothesized that right-handers tend to rotate the figure which is placed on the right side and that left-handers tend to rotate the figure on the left.

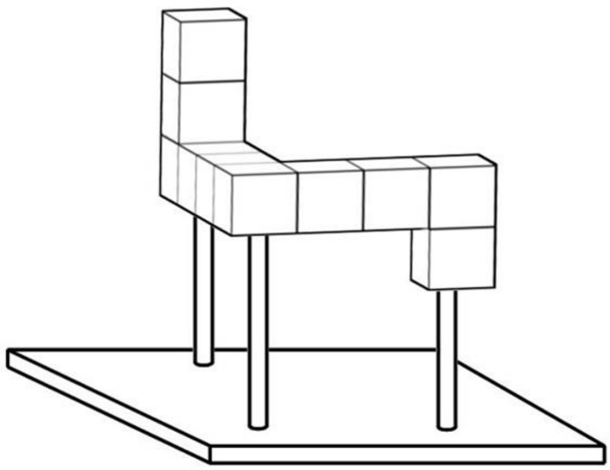

Figure 19: Cube object fixed on a base.

In order to answer this question, the participants in the Shepard Task replication implemented in this dissertation were visually prompted to rotate certain objects mentally. The items that were shown forced the participants to choose one particular object as a reference object, which would not be the one rotated mentally. This was achieved by placing one of the two depicted objects on a base (see Figure 19). Furthermore, this reference object was shown in an angular condition that suggested that this object was already in its original state. Consequently, there was no need to rotate this object mentally into its initial state. The second object of the picture pairs was shown in the same way as in the original Shepard Task. It conveyed the impression of a levitating object.

In this replication each of the 40 participants (20 right-handers and 20 left-handers) were shown 384 items consisting of the previously described cube objects. Twelve different cube objects were used for this experiment. The participants sat in front of a 16.4 inch LCD screen. The distance between the participants and the screen averaged 50 centimeters. In order to reinforce the impression of one fixed and one levitating object per item, the participants were given a short introduction. They were asked to imagine they are in an art museum and that they have to take part in a rally. They walk through different rooms. In each of these rooms two sculptures are placed. One of the sculptures is bolted to rods, the other sculpture floats in a large transparent water tank. The task was to look at one pair after another and to decide as quickly as possible whether the floating figure can be rotated into congruence with the bolted one. The participants’ choice was expressed by pushing one of two buttons on a gamepad. The green button had to be pushed in situations in which both depicted objects were judged as congruent. The red button had to be pushed when the participants thought the objects were different shapes. Half of the subjects used a gamepad with the red button on its left side and the green button on its right side; for the other half of the participants, the arrangement was reversed.

As in Shepard and Metzler’s task, one half of the items showed congruent objects (Figure 20, A & B). The other half showed incongruent ones (Figure 20, C & D).

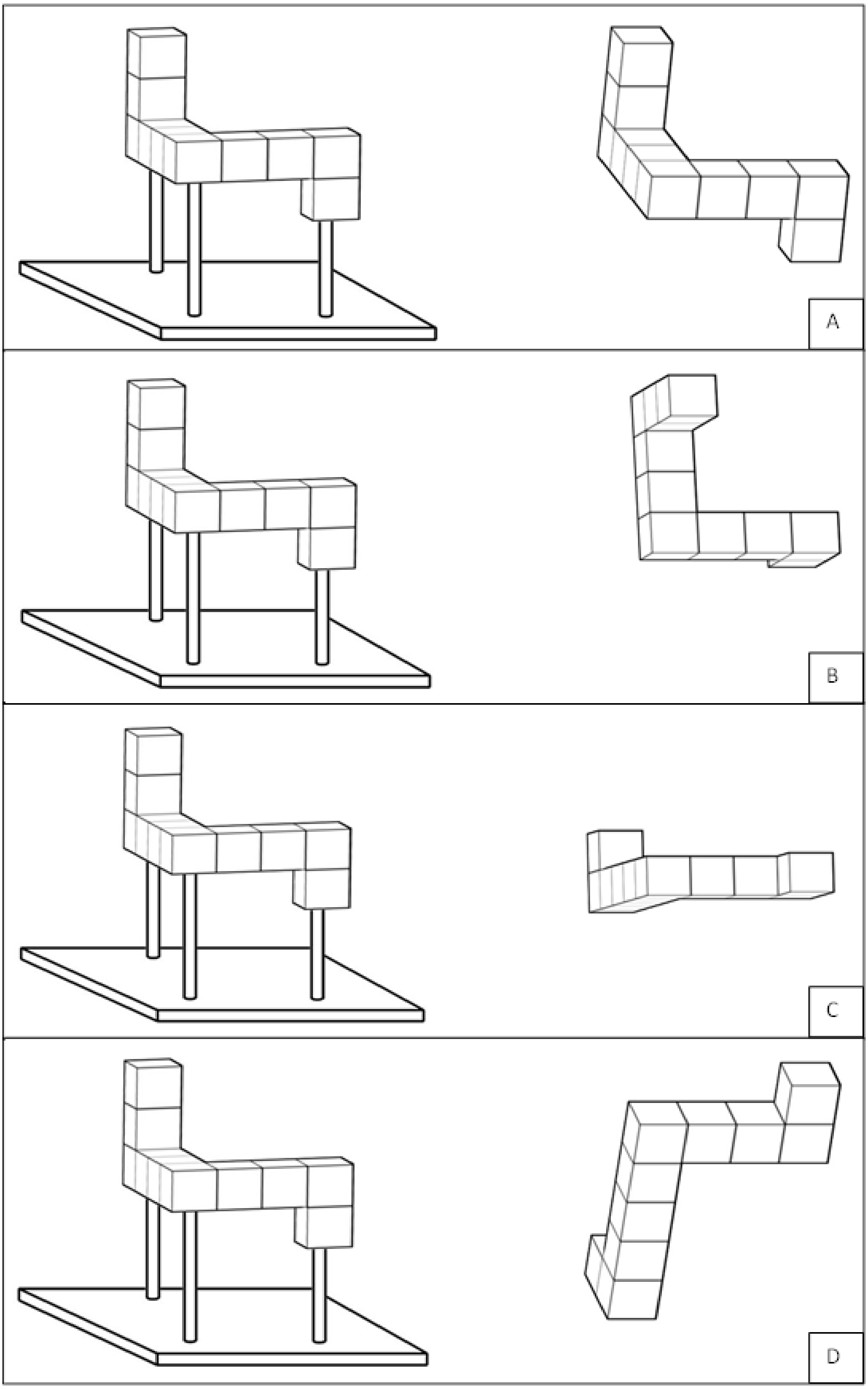

Figure 20: An excerpt of the items used in the replication of the Shepard Task.

As in the original experiment, the levitating objects were rotated either on the x-axis or on the z-axis. The rotation level varied. The base object and the reference object differed by a rotation level of at least 10 degrees and at most 70 degrees. In addition to these extreme values the reference objects were also rotated by 30 and 50 degrees. The rotation was carried out in both directions, so that in total every reference object was depicted in eight different states. A weak deviation from the initial state is depicted in Figure A and C, while a strong deviation is shown in Figure B and D. The condition in which the base object and reference object are equally rotated has been omitted. This should ensure that participants consistently pay a high level of attention to the task, and is also motivated by practical considerations. Rotation levels of 0, 20, 40, 60 and 80 degrees would have caused the problem of the depiction of a shape which would have appeared two-dimensional and therefore not been clearly recognizable (Figure 21). This difficulty also caused the omission of the rotation level of 90 degrees in the chosen gradation of rotation states.

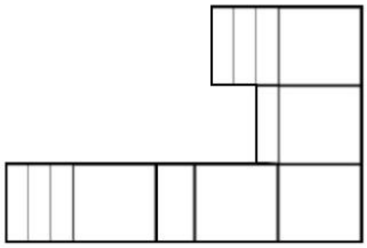

Figure 21: Object rotated by 80 degrees

The 384 items were shown in eight blocks. After each block the participants had the chance to take a break. The duration of this break was determined by the participants. When they were ready for the next sequence they had to signal this by pressing the appropriate button on the gamepad. In each of these blocks 24 congruent and 24 incongruent items were shown. The order of the depicted items was not random. In order to prevent an accidental occurrence of four or more successive incongruent or congruent objects, the order was set in advance. After every one of these sequences, the side on which the base object was placed was changed. The order was counterbalanced across the subjects.

7.2 Results

7.2.1 Reaction times

In Shepard and Metzler (1971), two main hypotheses were articulated. The first one was that the reaction time needed to judge a pair of cube objects to be congruent or incongruent stands in a linear relation to the extent of the angular deviation from the initial position. This phenomenon could also be found in the replication conducted here (Figure 22).

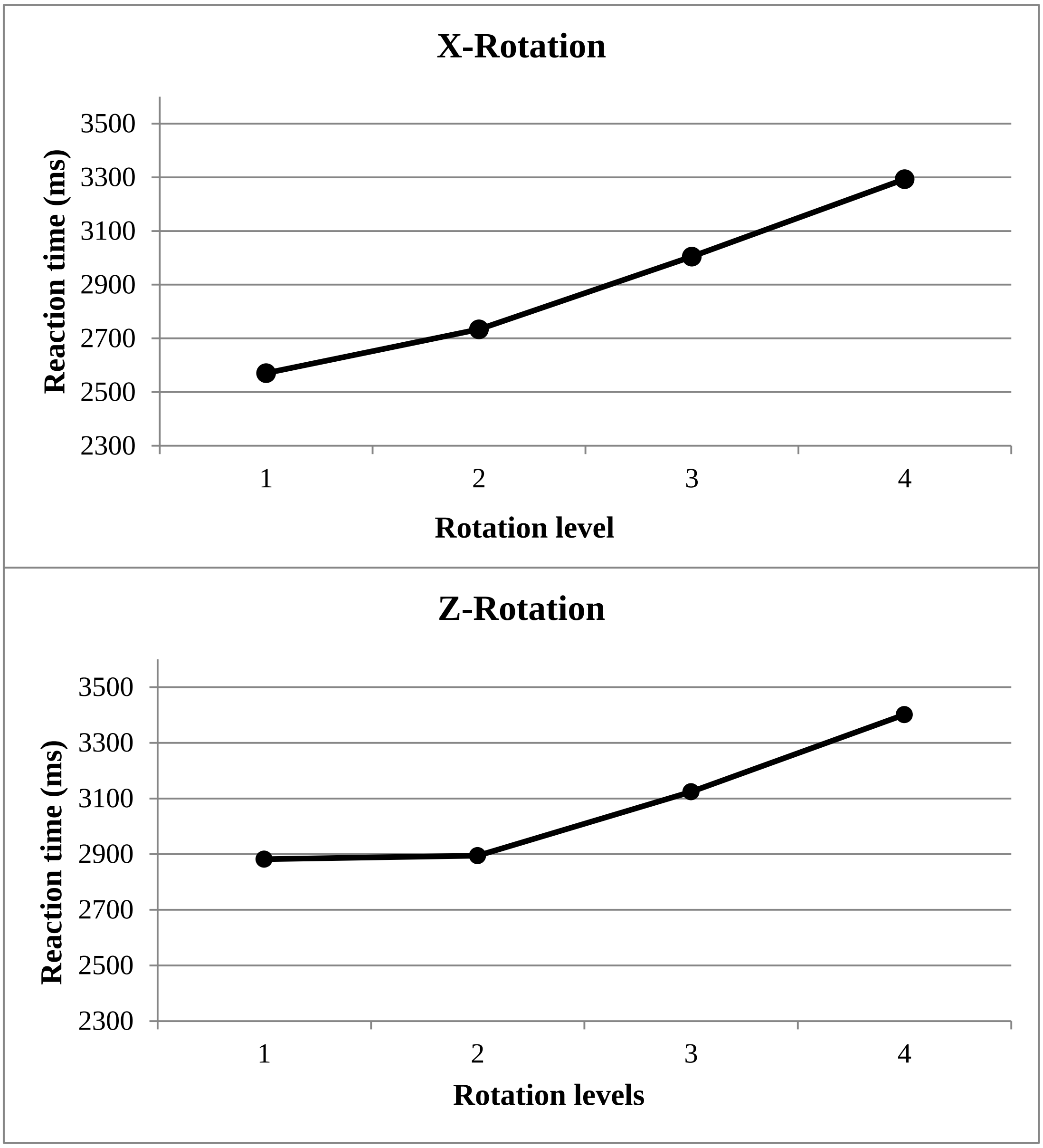

Figure 22: Relation of reaction times to degree of rotation, for different axes of rotation

Both diagrams depict proportional functions. The former shows the accumulated reaction times for items that were rotated around the x-axis of an imaginary coordinate system, the latter shows the reaction time for items that were rotated around the z-axis. It is obvious that both graphs display the same trend: the larger the angle between the base object and the rotated object, the longer the subjects required for their decision.

In order to analyse this increase of reaction time in detail, every rotational level was compared with the next higher one. The numerical difference of reaction time between the rotation levels was evaluated using a mixed model in R, evaluated by a Monte Carlo Markov chain estimation with 50,000 simulations. In order to determine the best matching and simplest mixed model, ANOVAs were conducted. The response time was used as the dependent variable. The factor ‘handedness’ embedded in the factor ‘display’ and, in addition, embedded in the factor ‘gamepad orientation’, as well as the factors ‘axes’ and ‘object congruence’ embedded in the different ‘rotation levels’ were used as independent variables and employed on the items as well as the subjects.

Rotation level	**Angular deviation**	**Mean RT (all)**	**Mean RT (left-handers)**	**Mean RT (right-handers)**
1	10°	2726 ms	2743 ms	2709 ms
2	30°	2814 ms	2791 ms	2838 ms
3	50°	3064 ms	3050 ms	3079 ms
4	70°	3347 ms	3256 ms	3441 ms

Table 7: The obtained reaction times in each rotation level

The results are depicted in Table 7, which shows the mean reaction times for each level of rotation. It can be observed that the time the subjects needed to judge an item to be congruent increases from step to step. This relationship is also revealed when one compares each rotational level to the next higher level. The difference from one level to the other was 20 degrees in each case. This same angular distance makes the single steps readily comparable with each other.

- Compared to level 1, in level 2 the reaction time increased by 88 seconds on average. A slight increase in reaction time can be seen, nevertheless this tendency is only significant at the .05 level ($t = 1.146$, $pMCMC = .022$).
- The comparison of level 2 and level 3 shows a highly significant increase of reaction time of 250 seconds on average ($t = 3.024$, $pMCMC = .002$).
- A similarly high significance can be observed in the comparison of level 3 and level 4. In this step, the reaction time increased by 283 seconds on average ($t = 3.093$, $pMCMC = .001$).

This comparison reveals that the increase of reaction time was significantly larger, the more the angle of the rotated objects deviated from the original image. That is, the graph has a consistently positive slope. However, the increase between the first and the second level is less significant. Figure 22 suggests that this deviation is attributable to the z-axis rotation, for which the reaction times at level 1 and level 2 are approximately equal. This is due to the structure of the used items. As already mentioned, objects rotated by 90 degrees were omitted in order to avoid ambiguous images being presented. In the case of the z-axis rotation, ambiguity could not be completely avoided, and consequently the recognition of objects rotated by 10 degrees may have been as difficult as the recognition of objects rotated by 30 degrees. The way the objects were depicted necessitated a closer look – and that required more time.

This leads to the second claim Shepard and Metzler (1971) made: “This reaction time is found (…) to be no longer for a rotation in depth than for a rotation merely in the picture plane” (p.701). This claim is not completely supported by the findings of the current experiment. On average, the participants were significantly faster in deciding that the item shows congruent objects in cases in which the reference object was rotated around the x-axis than around the z-axis (t = 3.36, pMCMC = .001). But, as argued above, this difference may stem entirely from the ambiguity that emerged in objects depicted at a level 1 rotation. Hence, this difference will be ignored in what follows.

It is also striking that the left-handed participants needed a little more time than right-handers to resolve these objects. This slight difference is depicted in Table 7 and in Figure 23. In the case of the x-axis rotation, the graphs closely resemble one another, whereas the graphs of the z-axis rotation revealed a larger deviation between level 1 and level 2. This deviation led to the relatively small increase in reaction time between these levels. Furthermore, it is striking that the left-handers not only required less time to recognize congruence in the second level of the z-axis rotation, but that the left-handers' graphs were generally flatter than the graphs of the right-handers. However, the difference in response time between right- and left-handers is not significant (t = 11.752, pMCMC = .7129). This apparent trend can again be explained by the small deviation caused by the ambiguous objects in level 1. Figure 23 shows that the left-handers were especially influenced by these ambiguities, which consequently caused an increase of reaction time at level 1, and contributes to the graph being apparently flatter across the four levels.

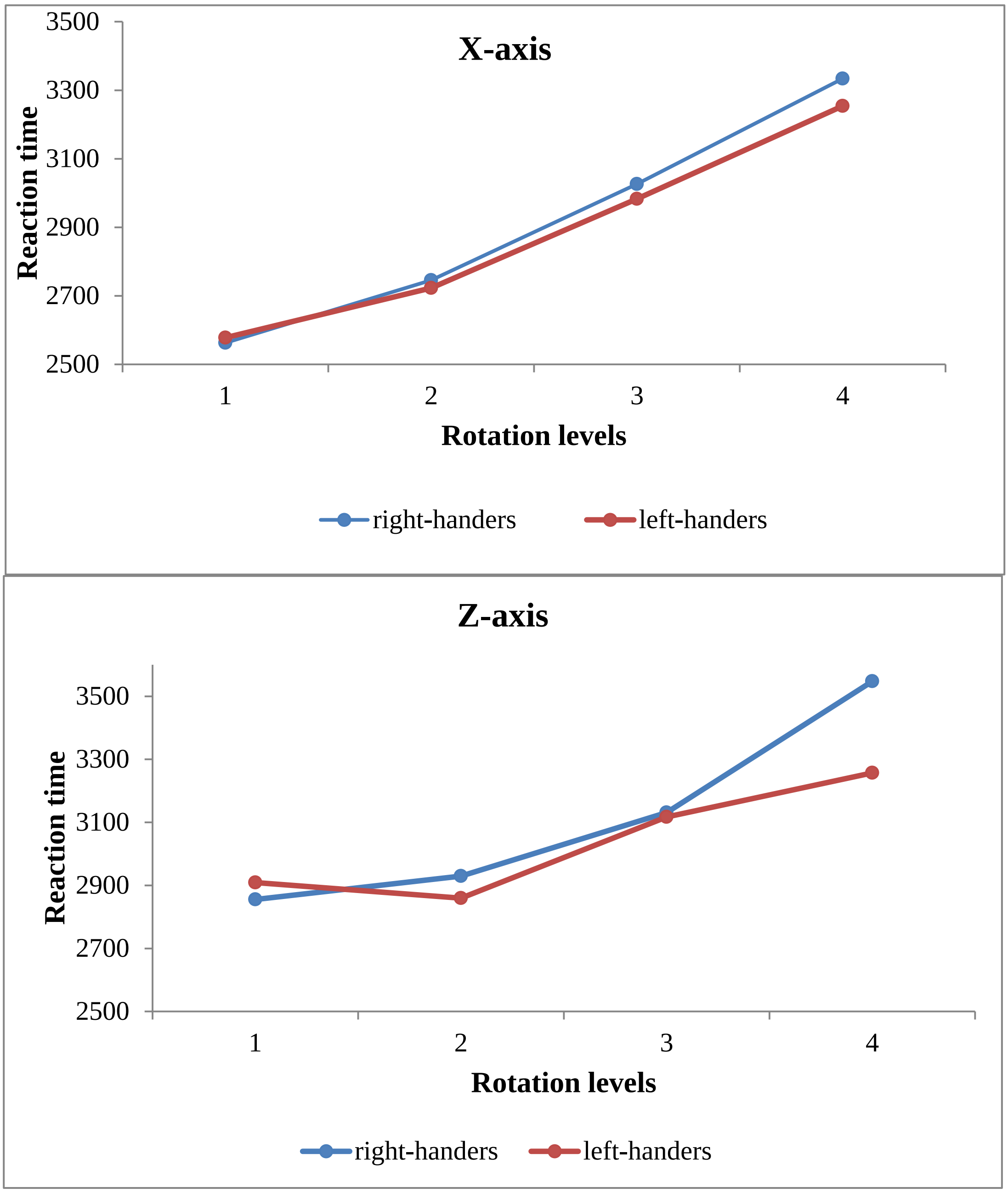

Figure 23: Reaction times with regard to handedness

Up to this point, the experiment has only confirmed the observations made in the original experiment (Shepard & Metzler, 1971) and in previous replications (for instance, Kuse & Vandenberg (1978) and Kirsh & Maglio (1994)). There are no new insights, but these results make it clear that the replication was successful. Now, the hitherto disregarded factor "base" will be included in the analysis. As noted earlier, the fact that one of the two depicted cube objects was fixed in each case had a relevant consequence:

this fixation made it possible to prompt the participants to rotate a certain object mentally and choose the other one as a reference object.

This effect of displaying the basis shape on each side of the screen was evaluated within left- and right-handers ($F(2) = 166.71$, $f = 0.159$). For modeling the hypothesized interaction, the factor "handedness" was defined as a group variable to mediate the effect of display, and hence the effect of display was evaluated in right- and left-handers separately. Again, the contrast was evaluated using a Monte Carlo Markov chain with 50000 simulations. In the case of the right-handers the effect of display under handedness turned out to be highly significant ($t = -18.142$, $p_{MCMC} < .0001$). The left-handers also exhibited a significant difference when judging the reference objects placed on the right side of the screen instead of on the left side of the screen ($t = 2.323$, $p_{MCMC} = .02$). This influence of this effect of side on the average reaction time is depicted in Figure 24.

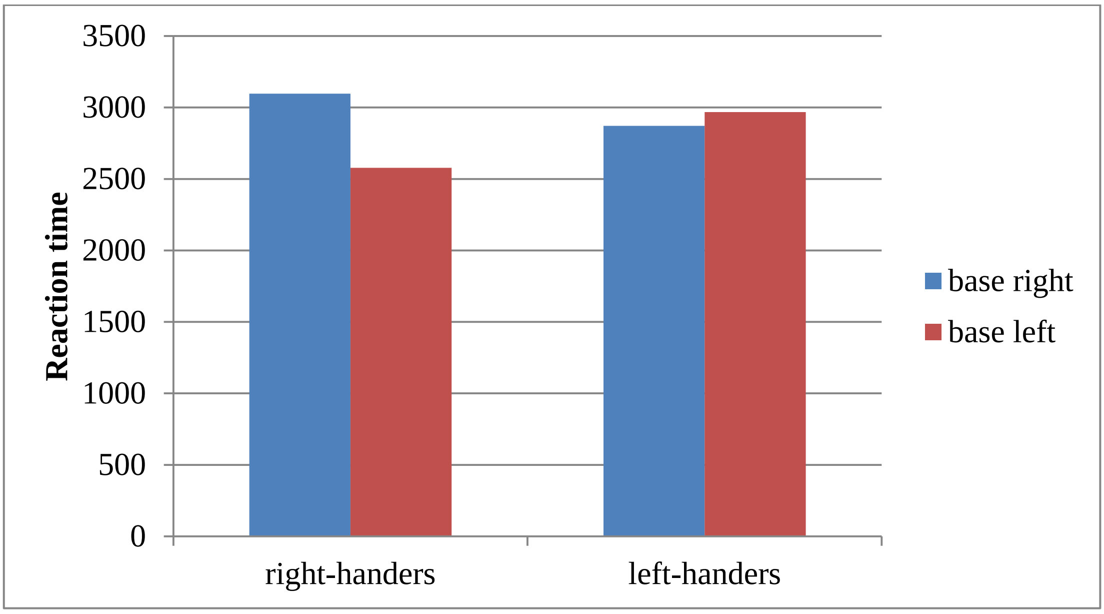

Figure 24: Reaction times with regard to the base

Shepard and Metzler (1971) argued that people simulate real rotation processes when performing mental rotations. Consequently, the further the figure is twisted, the greater the distance it has to cover to return to the starting position, as in the case of real rotation. This theory explains the increasing response time with increasing angular size between the original and the rotated object. This increase in response time was replicated in this experiment, as shown in Figure 23. As explained above, this increase was not completely linear, but deviations from a linear effect were minor and could have been caused by visual ambiguities. Thus, these deviations are negligible. So, for the sake of simplicity, the further analysis uses completely linear functions.

The following linear graphs arose from the mapping of point clouds, which display the reaction time as a function of the rotational levels. Each point of this point cloud corresponds to one trial. Initially, this procedure was carried out for each subject. Those items which showed the base object on the right side were treated separately from those with the base object on the left side, in order to illustrate the consequences of the manipulation in detail. In a second step, a trend line was drawn. This procedure revealed predictable general differences in the reaction times from one subject compared to another – but a significant large number of subjects exhibited an effect of side. Figure 25 shows two examples of these reaction time effects, in the case of two right-handers.[11] As in the previous diagrams, the abscissa represents the rotation level and the ordinate maps the reaction time.

[11] Figure 25 shows only two examples out of the group of right-handers. The reason for this is that this group developed a particularly strong and highly significant effect and therefore offers the more interesting diagrams.

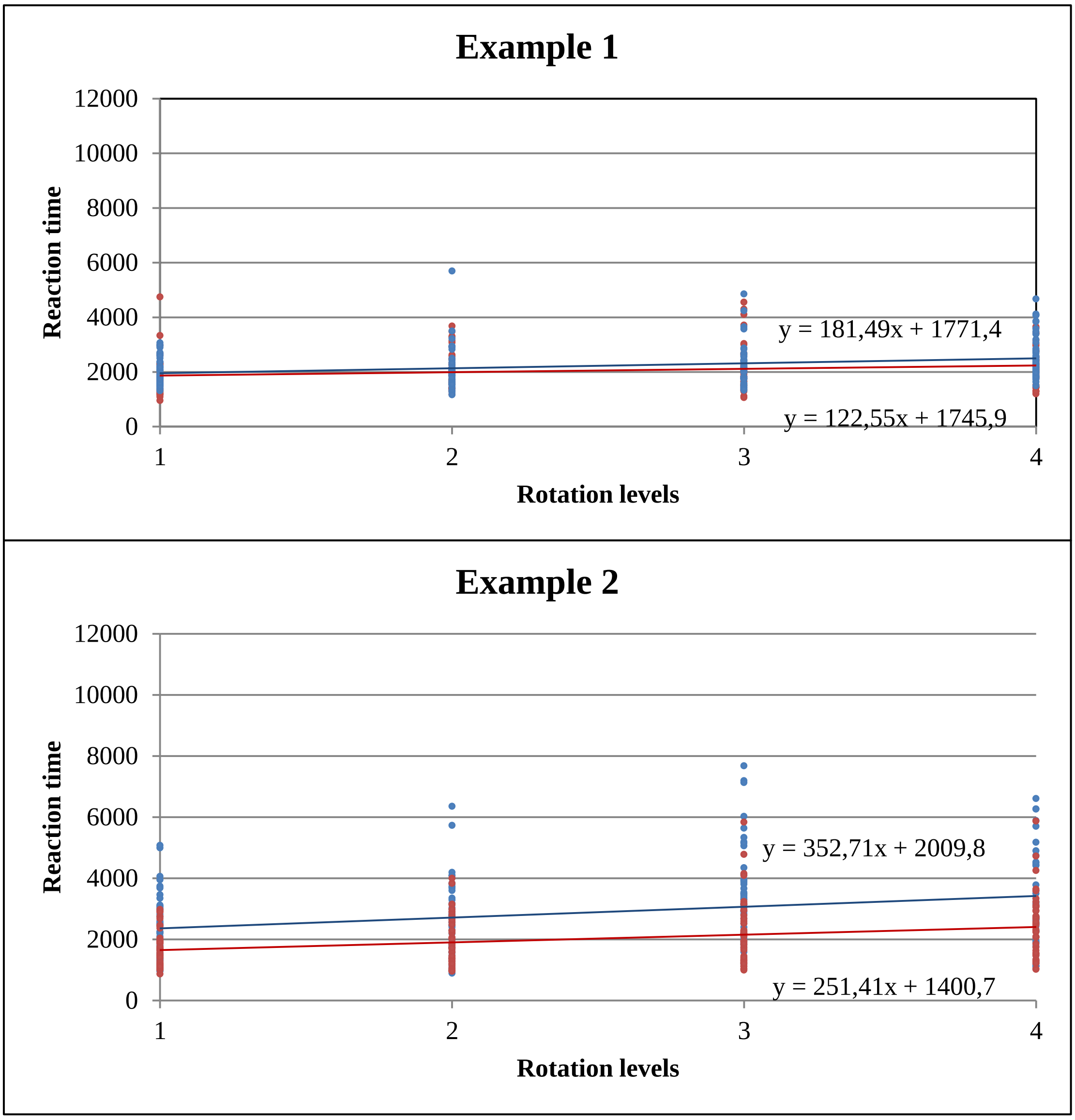

Figure 25: Reaction times of two right-handed participants depending on the rotation levels.

Both graphs reveal the fact that right-handers tend to have shorter reaction times, if they can mentally rotate the figure on the right. In a next step, the point clouds of the right-handed participants were accumulated. The same was done in the case of the left-handed participants. Hence, this procedure was carried out for four separate sets of data.

- Figure 26 A depicts the point clouds for all decisions in which right-handers saw the base figure on the left.
- Figure 26 B depicts the point clouds for all decisions in which right-handers saw the base figure on the right.

- Figure 26 C depicts the point clouds for all decisions in which left-handers saw the base figure on the left.

- Figure 26 D depicts the point clouds for all decisions in which left-handers saw the base figure on the right.

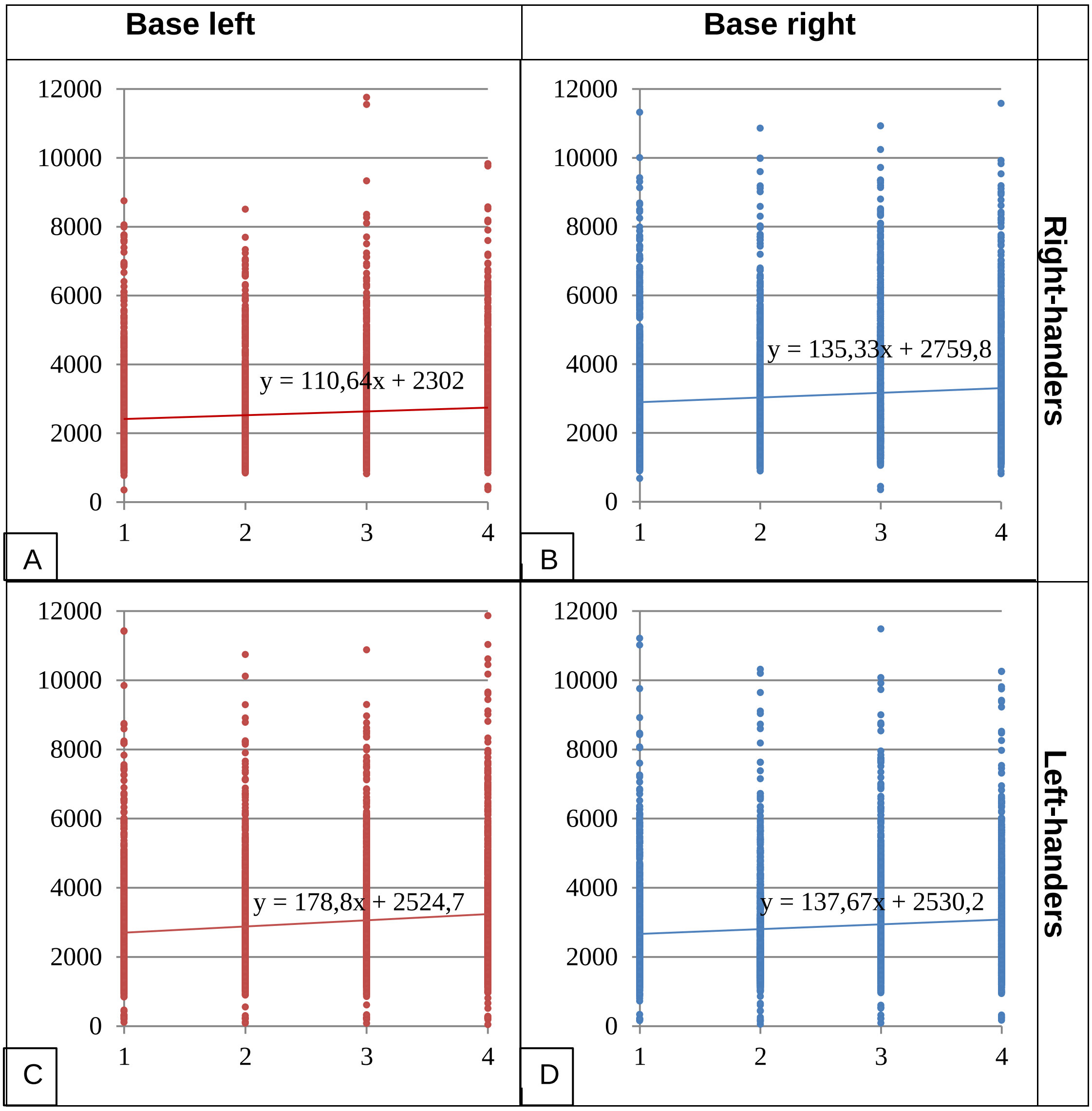

Figure 26: Developments of reaction times shown with point clouds

Regression over these data sets creates four new linear functions, the coefficients of which are also shown in Figure 26. The curves in which the rotated object was placed on the dominant side of the subjects had a lower slope. In the case of right-handers, the intercept was also substantially smaller.

As already mentioned, the rotational levels signify the different sized angles between the starting position and the rotated figure. Going one step further, we can use these functions to estimate the angular velocity of the participants' mental rotations, for each of the four different conditions. To calculate this angular velocity, the rotational levels have been replaced by angular sizes in radians. In a second step, the difference between the reaction times as a function of the radians made it possible to determine the angular velocity using the formula $\vec{\omega} = \Delta\varphi / \Delta t$. This approach reinforced the significant influence of the position of the base figure on the behavior of subjects (Figure 27).

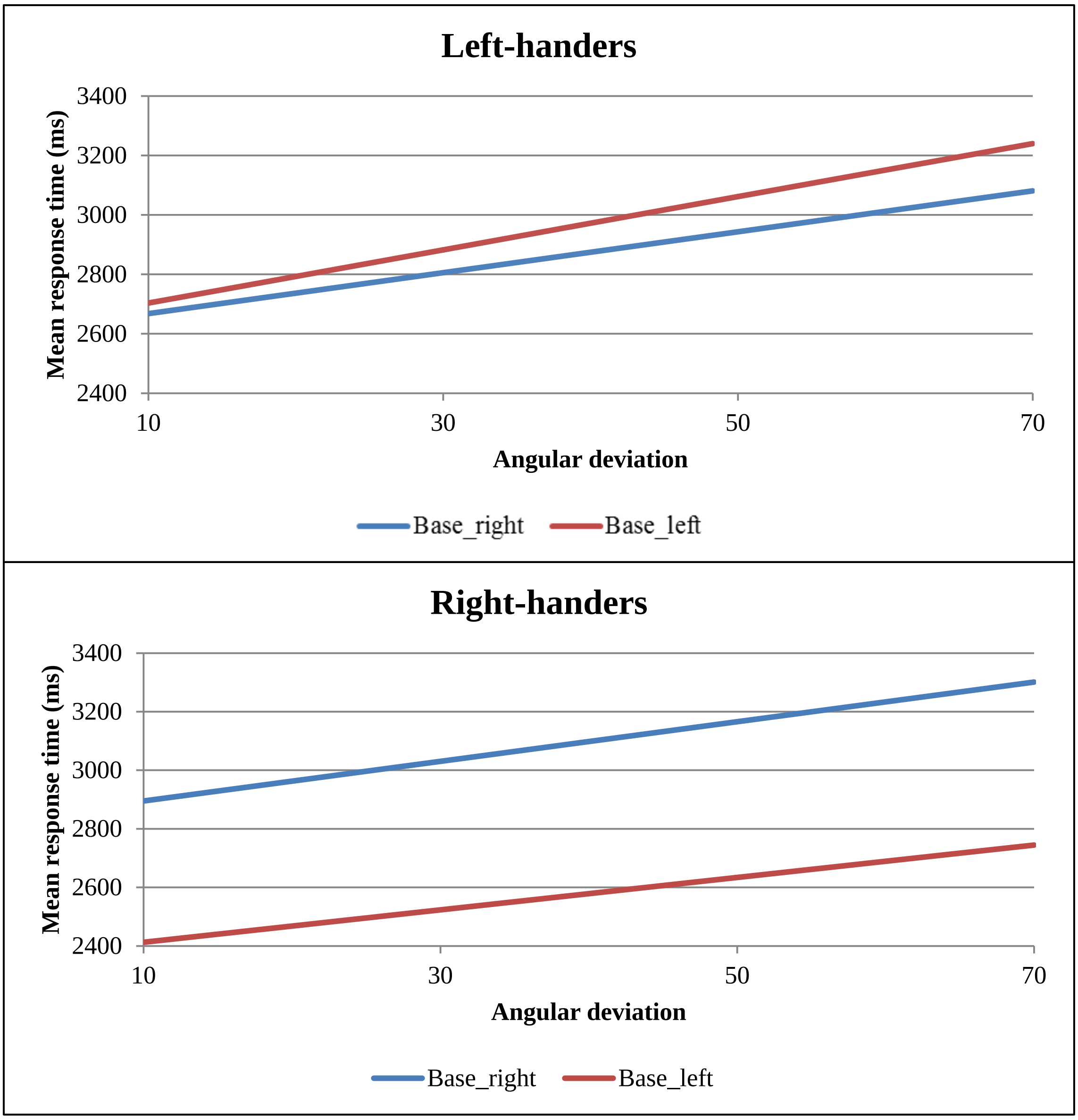

Figure 27: Calculation of the angular velocity

- The right-handed subjects mentally rotated on average at 3.16 rad/s with their right and consequently preferred mental hand, and at 2.58 rad/s with their left and consequently non-preferred mental hand.

- The left-handed subjects mentally rotated on average at 2.54 rad/s with their left and consequently preferred mental hand, and at 1.95 rad/s with their right and consequently non-preferred mental hand.

As these were calculated by the formula $\vec{\omega} = \Delta\varphi / \Delta t$, the four quoted values for angular velocity do not include the intercept. The presented values only depict the slope of the graphs depicted in Figure 27 and, thus, “ignore” the starting point. For this reason, the four values create the impression that the right-handers were faster than the left-handers. It is therefore crucial to note that the intercepts shown in Figure 27 differ in the predicted directions:

- Left-handers were faster than right-handers.

- The difference between the criteria “base-right” and “base-left” were bigger in the case of the right-handed participants.

Both were disregarded in the calculation of angular velocity. Thus, the four values only serve as an indication of how rapidly the participants were able to perform rotation over additional distances. The angular velocity indeed shows that right-handers and left-handers were both faster when rotating with their preferred mental hands. That is, the increase in angular deviation affects reaction time less when acting with the preferred hand.

These results demonstrate again that left-handers were averagely slightly faster than right-handers. But furthermore, they show that the subjects performed mental rotation more fluently when the object which had to be rotated was positioned on the dominant side. This agrees completely with the participants’ statements after performing the experiment. The participants were asked whether they had noticed anything. Subsequently, 17 of the 40 participants expressed that they had noticed an increase of difficulty each time the base figure was placed on a particular page. Eleven of these 17 participants were right-handers; the remaining six participants were left-handed. In this context it is highly noteworthy that all these right-handed participants expressed the subjective assessment that it was more difficult to rotate the object on the left. In the case of the left-handers, the perception was the other way around.

7.2.2 Error rates

The errors also patterned analogously to those in the original experiment (1971). The participants judged more congruent items to be incongruent the greater the angular difference was between the base and the rotated figure.

- In level 1, the error rate averaged at 4.2 percent and increased at level 2 by 0.6 percent. This difference is not significant ($z = 0.683$, $p = .495$)[12].
- In level 2, the error rate averaged at 4.8 percent and increased at level 3 by 2.3 percent. This difference is significant ($z = 2.510$, $p = .012$).
- In level 3, the error rate averaged at 7.1 percent and increased at level 4 by 3.0 percent. This difference is highly significant ($z = 5.037$, $p < .001$).

This development of errors is depicted in Figure 28, which concentrates on the average of the x-axis rotation and the z-axis rotation. The separate analysis of both is not necessary in this case, since the subjects did not act significantly differently when working with the x-axis instead of the z-axis ($z = 1.554$, $p = .120$).

[12] This is due to the ambiguity of the images and is therefore in no way in conflict with the findings of Shepard and Metzler (1971). This discrepancy was already explained in the course of the analysis of reaction times in detail.

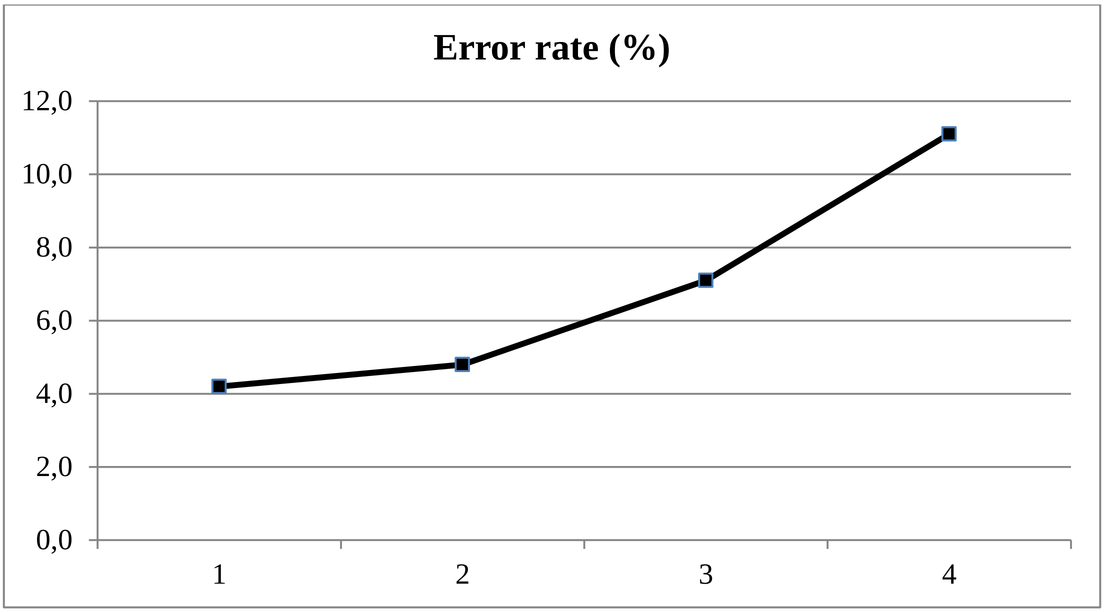

Figure 28: Development of the error rate across rotations

In fact, the error rates remained mostly unaffected by the side at which the base object was placed. This is illustrated by the bar charts in Figure 29, which depict the error rates as a percentage. This illustration separates the results of the right-handed participants from the results of the left-handed participants and includes errors in which congruent objects were falsely judged as incongruent as well as those in which incongruent objects were falsely judged as congruent.

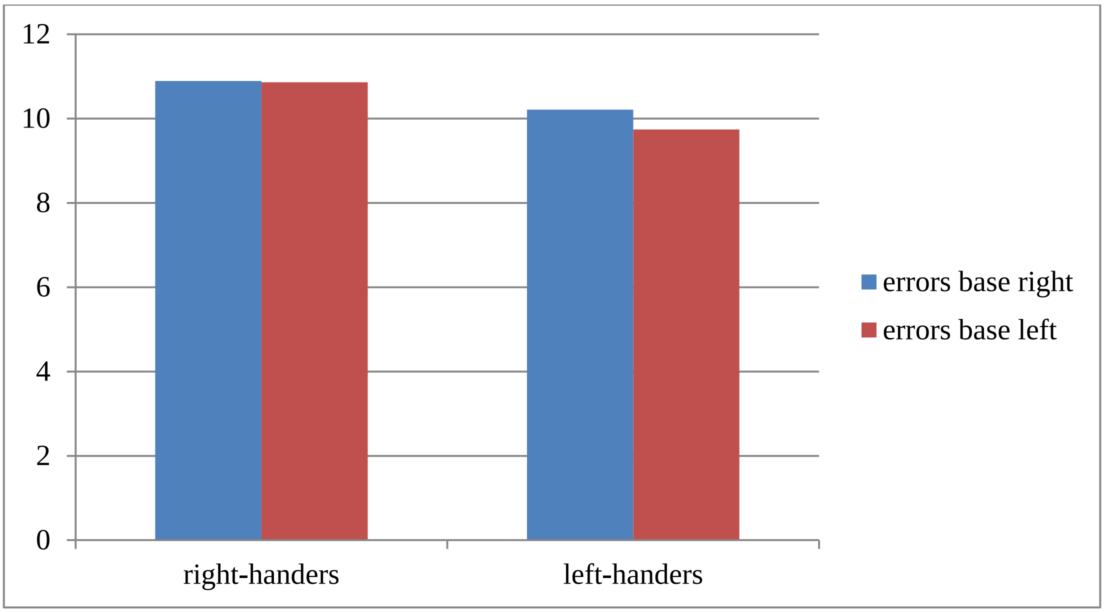

Figure 29: Developments of error rate with regard to the base

In both groups, the right-handers and the left-handers, the error rate amounted on average to around ten percent. The left-handers made fractionally fewer mistakes than the right-handers, but this difference is not significant ($z = 1.309$, $p = 0.191$). As Figure 29 shows, the error rate of the right-handers ($z = 0.353$, $p = 0.724$) and the left-handers ($z = 0.625$, $P = 0.532$) remained unaffected by the side on which the base object was placed.

7.3 Discussion

This slightly altered replication of the Shepard Task achieved three main results. First, it closely replicated the results of the original experiment (Shepard & Metzler, 1971). In particular, the positive linear function between reaction time and angular difference was comparable to that observed in the original Shepard Task. Secondly, it provided evidence in support of the described theories concerning the mental and physical differences between right- and left-handers. As the results gained by Santrock (2008), Judge and Stirling (2003) and Widerman et al. (2011) suggested, left-handers have better skills in solving visual-spatial tasks. This is obviously also applicable to tasks that they perform with their non-dominant hand – hence, the difference between the non-dominant hand and the dominant hand is not as marked as in the case of the right-handers. Both claims were also supported by the findings of this replication, which indicated that left-handers are faster than right-handers in judging rotated objects to be congruent regardless of on which side the rotated object is placed.

Thirdly, this experiment makes completely new observations. In prior work, participants were not restricted in choosing an object as a reference, which made it impossible to characterize some potential regularities. Fixing one of the two displayed objects on a base addressed this limitation. Right- and left-handers do indeed seem to prefer to rotate an object placed next to their dominant side. This suggests that the principle that acting with the dominant hand leads to greater fluency is just as applicable to mental rotation tasks as to other virtual movement tasks. Since Cohen et al. (1996) already figured out that mentally simulated manipulations of objects and actual manipulations involve the same brain areas, some slight effect of handedness could be expected. Nevertheless, the extent of the effect caused by a few centimeters' distance between the fixed object and the rotated one on the screen was surprising.

Of course, we did not discover the reasons that underpin the well-marked preference for participants to rotate an object placed on their dominant side. A clear understanding of this would require further investigation. It is possible, however, that the participants were simply accustomed to regarding objects while holding and rotating them in their dominant hand. This would predict that the right-handers and left-handers were only slowed down because of the irritation caused by the unusual perspective of a rotated object being placed on the "wrong" side of the screen. However, the less-marked effect in the group of left-handers leads to another hypothesis. As Judge and Stirling (2003) claimed, the difference between dominant and non-dominant hand is not as great for left-handers as for right-handers. This is due to the fact that left-handers have to live in a world which is made for right-handers. In order to manage everyday situations left-handers have to come to terms with scissors or door handles made for the needs of right-handers. Indeed, there is no need to regard an object while holding it in the non-dominant hand. If the mental simulation of object manipulation is strongly embodied, mental rotation would not only refer to simulating the rotation of the objects, but also the tools that are needed to perform a physical rotation – in this case, the right or the left hand. This is consistent with the smaller effects observed in the left-handers as well as with Wilson's (2002) claim that *off-line cognition is body-based*. In the mental simulation of object manipulations, people seem to have the same strengths and weaknesses as in physical simulation situations. Thus, people have two pairs of hands – a real and a mental one.

8. Manipulation-specificity in real and virtual acting

The *manipulation-specificity hypothesis* states that the impact of handedness is only relevant in *active placement tasks* and not in *perceptual judgment tasks*, since people seem to act the way they do only for reasons of comfort. Within the framework of this dissertation, I suggested the idea that people place superior objects in a way that guarantees optimal accessibility. However, they do not consider the placements to be positive or negative aspects of the objects. This foregrounds the extreme economy people reveal in active placement tasks: they tend to ensure that more useful objects are close to the hand that is more highly developed and probably able to grasp and manipulate the object more precisely and more quickly when the need arises. There is simply no logical reason why people should place an object close to the hand with which they would never use this object. These assumptions were successfully proved in implementing the first two experiments and reveal that the results of prior experiments testing the body-specificity hypothesis were only slightly misunderstood and overstated.

Since *off-line cognition is body-based* (Wilson, 2002), I also proposed that handedness would have an impact on the ability to move virtual objects mentally and the fluency people display in these tasks. The replication of the *Shepard Task* supported this hypothesis by showing that right-handers and left-handers do indeed seem to solve mental rotation tasks differently. Left-handers prefer virtually rotating objects placed on the left and right-handers tend to virtually rotate objects placed on the right – and people do not feel comfortable when being forced to act differently. This also fits with the results from the Shopping Tour and the Supermarket Manager task.

So, the restrictions of the body obviously do not leave mental abilities untouched. This has already been supported by previous investigations. As discussed in section 6.4, Rietsch and Jansen (2012) revealed that people with outstanding musical or athletic abilities also display extraordinarily developed mental rotation abilities. This again hints towards the correlation between real and virtual acting. Athletic and musical people have one important aspect in common – they are extremely well-coordinated in their physical actions. Since they also have to simulate certain movements in training or rehearsal, they are consequently more practiced and skilled in performing mental actions.

Moreover, the body does not merely restrict the mind, but also serves as a catalyst. This is also backed up by Wilson's (2002) observation that people use their body as a tool while finger-counting or gesturing. This again points to the economy with which people solve certain problems. Without the body's help such tasks would be much more effortful to solve. The Tetris experiment performed by Kirsh and Maglio (1996) also gave a hint toward to this economy theory by revealing that people tend to use visual help in solving mental rotation tasks.

All these aspects cohere and reveal that the manipulation-specificity hypothesis is at once a theory that points to the link between real and mental manipulation of objects and a theory that highlights the economy with which people solve active placement as well as mental simulation tasks. In a very literal sense, people are equipped with two pairs of hands, a real and a mental one. This implies that the features of a body also impinge on the mind. When a person is left-handed in the real world, the person is also a left-hander in his mind. When a person is well-coordinated in the real world, the person shows the same feature in her mental actions. But first and above all, when a person solves a manipulation task mentally or in reality, this person always does this as economically as possible – and makes use of the close link between body and mind. Thus, mental acting indeed seems to be embodied, but judging does not.

9. Bibliography

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577–660.

Beilock, S. L., & Holt, L. E. (2007). Embodied preference judgments: Can likeability be driven by the motor system? *Psychological Science, 18,* 51–57.

Bonda, E., Petrides, M., Frey, S., & Evans, A. (1995). Neural correlates of mental transformations of the body-in-space. *Proceedings of the National Academy of Sciences of the United States of America*, 92, 11180–11184.

Bruce, V., Green, P., & Georgeson, M. (1996). *Visual Perception: Physiology, Psychology and Ecology* (3rd ed.). LEA.

Bussmann, H. (1996), *Routledge Dictionary of Language and Linguistics*. London: Routledge.

Carnap, R. (1947). *Meaning and Necessity: A Study in Semantics and Modal Logic*. Chicago: University of Chicago Press.

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology, General: 138,* 351–367.

Casasanto, D. & Chrysikou, E. G. (2011). When Left is "Right": Motor fluency shapes abstract concepts. *Psychological Science, 22(4),* 419–422.

Casasanto, D. & Henetz, T. (2012). Handedness shapes children's abstract concepts. *Cognitive Science, 36,* 359–372.

Casasanto, D. & Jasmin, K. (2010). Good and bad in the hands of politicians: Spontaneous gestures during positive and negative speech. *PLoS ONE*, 5(7), e11805.

Chatterjee, A. (2001). Language and space: Some interactions. *Trends in Cognitive Science, 5,* 55–61.

Chomsky, N. (1968). *Language and Mind*. New York: Harcourt, Brace and World.

Cohen, M., Kosslyn, S. M., Breiter, H., DiGirolamo, G. J., Thompson, W., Anderson, A. K., et al. (1996). Changes in cortical activity during mental rotation: A mapping study using functional magnetic resonance imaging. *Brain*, 119, 89–100.

Cooper, L. A. (1975). Mental rotation of random two-dimensional shapes. *Cognitive Psychology,* 7, 20–43.

Cooper, L. A. (1976). Demonstration of a mental analog of an external rotation. *Perceptual Psychophysics*, 19, 296–302.

Corballis, M. C., & Beale, I. (1976). *Psychology of Left and Right.* Hillsdale, NJ: Erlbaum.

Corballis M. C. (2003). From mouth to hand: gesture, speech and the evolution of right-handedness. *Behavioral and Brain Sciences, 26*, 199–208.

Cramér, H. (1999). *Mathematical Methods of Statistics*. Princeton, NJ: Princeton University Press.

Darwin, C. (1872). *The Expression of the Emotions in Man and Animals*. New York: D. Appleton and Company.

De Saussure, F. (1916). The nature of the linguistics sign. In C. Bally & A. Sechehaye (Ed.), *Cours de linguistique générale*. McGraw Hill Education.

Descartes, R. (1641) *Meditations on First Philosophy*. In *The Philosophical Writings of René Descartes*, translated by J. Cottingham, R. Stoothoff, & D. Murdoch. Cambridge: Cambridge University Press, 1984, vol. 2, pp. 1–62.

Fakultät für Sportwissenschaften, Universität Leipzig: Auswertung „Edinburgh Handedness Inventory“, URL: http://sportfak.uni-leipzig.de/~iabtw/laboruebung/Uebung_Stoeckel/Auswertung%20Seitigkeitstests.pdf (retrieval: 20th February 2012).

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149–1160.

Frege, G. (1892). Über Sinn und Bedeutung. *Zeitschrift für Philosophie und philosophische Kritik, 100*, 25–50.

Gallagher, S. (2005). *How the Body Shapes the Mind*. Oxford: Oxford University Press.

Gallese, V. S., & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology, 22,* 455–479.

Gibbs, R. W. (1994). *The Poetics of Mind: Figurative Thought, Language, and Understanding*. New York: Cambridge University Press.

Gibson, J. J. (1974). Visualizing conceived as visual apprehending without any particular point of observation. *Leonardo, 7,* 41–42.

Glenberg, A. M. (1997). What memory is for. *Behavioral and Brain Sciences,* 20, 1-55.

Goldstone, R., & Barsalou, L. (1998). Reuniting perception and conception. *Cognition, 65,* 231–262.

Heinzel, F. (20th February 2008). Warum Linkshänder im Sport erfolgreicher sind In: Welt Online. URL: http://www.welt.de/wissenschaft/article1698534/Warum_ Linkshaender_im_Sport_erfolgreicher_sind.html (Retrieved 29 July 2012)

Hochberg, J., & Gellman, L. (1977). The effect of landmark features on mental rotation times. Memory and Cognition, 5, 23–26.

Ionta, S., & Blanke O. (2009). Differential influence of hands posture on mental rotation of hands and feet in left and right handers. *Experimental Brain Research*. 195 (2), 207–217.

Jasmin, K., & Casasanto, D. (2012). The QWERTY Effect: How typing shapes the meanings of words. *Psychonomic Bulletin and Review,* DOI: 10.3758/s13423-012-0229-7.

Judge, J., & Stirling, J. (2003) Fine motor skill performance in left- and right-handers: Evidence of an advantage for left-handers. *Laterality*, 8(4), 297–306.

Just, M. A., & Carpenter, P. A. (1976). Eye fixations and cognitive processes. *Cognitive Psychology,* 8, 441–480.

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science,* 18, 513–549.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the Flesh: The Embodied Mind and its Challenge to Western Thought*. Chicago, IL: University of Chicago Press.

Levy. J (1973). Lateral specialization of the human brain. Behavioral manifestations and possible evolutionary basis. In J. Kiger (Ed.), *The Biology of Behavior.* Oregon: Oregon State University Press.

Levy, J., & Reid, M. (1978). Variations in cerebral organisation as a function of handedness, hand posture in writing, and sex. *Journal of Experimental Psychology, 107,* 119–144.

Marley, S. C., Levin, J. R., & Glenberg, A. M. (2010). What cognitive benefits does an activity-based reading strategy afford young Native American readers? *Journal of Experimental Education, 78,* 395–417.

Martinet, A. (1955). *Economie des changements phonètiques. Traitè de phonologie diachronique*. Bern: Francke.

Maxwell, J. S., & Davidson, R. J. (2007). Emotion as motion: asymmetries in approach and avoidance actions. *Psychological Science*, *18,* 1113–1119.

Metzler, J., & Shepard, R. N. (1982). Transformational studies of the internal representation of three-dimensional objects. In R. N. Shepard & L. A. Cooper (Eds.), *Mental Images and their Transformations* (pp. 25-71). Cambridge, MA: MIT Press.

Michel-Ange, A., Isableu, B., & Jarraya, M. (2006). Embodied spatial transformations: “body analogy” for the mental rotation. *Journal of Experimental Psychology: General, 135*, 327–347.

Moreau, D., Mansy-Dannay, A., Clerc, J., & Guerrién, A. (2011). Spatial ability and motor performance: Assessing mental rotation processes in elite and novice athletes. *International Journal of Sport Psychology*, 42(6), 525–547.

Noë, A. (2004). *Action in Perception*. Cambridge, MA: MIT Press.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9,* 97–113.

Parsons, L. H., Fox, P. T., Downs, J. H., Glass, T., Hirsch, T. B., Martin, C. G., et al. (1995). Use of implicit motor imagery for visual shape discrimination as revealed by PET*.* *Nature*, 375, 54–58.

Pertsch, E. (Ed.) (2007). *Handwörterbuch. Lateinisch–Deutsch*. München: Langenscheidt.

Pietsch, S., & Jansen, P. (2012). Different mental rotation performance in students of music, sport and education. *Learning and Individual Differences*, 22(1), 159–163.

Podgorny, P., & Shepard, R. N. (1978). Functional representations common to visual perception and imagination. *Journal of Experimental Psychology: Human Perception and Performance, 4,* 21–35.

Podgorny, P., & Shepard, R. N. (1983). The distribution of visual attention over space. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 380–393.

Previc, F. H. (1991). A general theory concerning the prenatal origins of cerebral lateralization in humans. *Psychological Review,* 98(3), 299–334.

R Core Team (2013). A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.

Riskind, J. H., & Gotay, C. C. (1982). Physical posture: Could it have regulatory or feedback effects on motivation and emotion? *Motivation and Emotion*, 6(3), 273–298.

Strack, F, Martin, L., & Stepper, W. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology, 54,* 768–777.

Santrock, J. W. (2008). Motor, sensory, and perceptual development. In M. Ryan (Ed.), *A Topical Approach to Life-Span Development* (pp.172–205). Boston, MA: McGraw-Hill.

Sattler, J. B. (1995). *Der umgeschulte Linkshänder oder Der Knoten im Gehirn.* Heidelberg: Auer Verlag.

Schubert, T. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89,* 1–21.

Shepard, R. N. (1975). Form, formation, and transformation of internal representations. In R. Solso (Ed.), *Information Processing and Cognition: The Loyola Symposium.* Hillsdale, NJ: Erlbaum.

Shepard, R. N. (1984). Ecological constraints on internal representations: Resonant kinematics of perceiving, imagining, thinking, and dreaming. *Psychological Review*, 91, 417–444.

Shepard, R. N., & Chipman, S. (1970). Second-order isomorphism of internal representations: Shapes of states. *Cognitive Psychology, 1,* 1–17.

Shepard, R. N., & Cooper, L. A. (1982). *Mental Images and their Transformations*. Cambridge, MA: MIT Press.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, 171, 701–703.

Simmons, W. K., Ramjee, V., Beauchamp, M. S., McRae, K., Martin, A., & Barsalou, L. W. (2007). A common neural substrate for perceiving and knowing about color. *Neuropsychologia, 45,* 2802–2810.

Stein, J. F., & Stoodley, C. J. (2006). *Neuroscience. An introduction*. Chichester: John Wiley & Sons.

Tettamanti, M., Buccino, G., Saccuman, M. C., Gallese, V., Danna, M., Scifo, P., Fazio, F., Rizzolatti, G., Cappa, S. F., & Perani, D. (2005). Listening to action-related sentences activates frontoparietal motor circuits. *Journal of Cognitive Neuroscience, 17*, 273–281.

Toga, A. W., & Thompson, P. M. (2003). Mapping brain asymmetry. *Nature Reviews Neuroscience,* 4(1), 37–48.

Trask, R. L. (1999). *Language: The Basics* (2nd edn.). London: Routledge.

Van den Bergh, O., Vrana, S., & Eelen, P. (1990). Letters from the heart: Affective categorization of letter combinations in typists and nontypists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 1153–1161.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills*, 47, 599–604.

Widermann, D., Barton, R. A., & Hill, R. A. (2011) Evolutionary perspectives on sport and competition. In S. C. Roberts (Ed.), *Applied Evolutionary Psychology*. Oxford: Oxford University Press.

Willems, R. W., Hagoort, P., & Casasanto, D. (2010). Body-specific representations of action verbs: Neural evidence from right- and lefthanders. *Psychological Science 21,* 67–74.

Willems, R. M., Labruna, L., D'Esposito, M., Ivry, R., & Casasanto, D. (2010). A functional role for the motor system in language understanding: Evidence from rTMS. In *Proceedings of the 16th Annual Conference on Architectures and Mechanisms for Language Processing [AMLaP 2010]* (pp. 127). York: University of York.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review, 9(4)*, 625–636.

Wood, C. J., & Aggleton, J. P. (1989). Handedness in ‘fast ball’ sports: Do left-handers have an innate advantage? *British Journal of Psychology, 80*, 227–240.

Wraga, M., Kosslyn, S. M., Thompson, W. L., & Alpert, N. M. (2003). Implicit transfer of motor strategies in mental rotation. *Brain & Cognition*, 52, 135–143.

Young, P. A., Young, P. H., & Tolbert, D. L. (2008). *Basic Clinical Neuroscience*. Baltimore, MD: Lippincott Williams & Wilkins.

Yuille, J. C., & Steiger, J. H. (1982). Nonholistic processing in mental rotation: Some suggestive evidence. *Perception & Psychophysics, 31*, 201–209.

Zhong, C. B., & Liljenquist, K. (2006). Washing away your sins: Threatened morality and physical cleansing. *Science*, 313, 1451–1452.

Zipf, G. K. (1949). *Human Behavior and the Principle of Least Effort*. Cambridge, MA: Addison-Wesley Press.

Zwaan, R. A., & Yaxley, R. H. (2003). Hemispheric differences in semantic-relatedness judgments. *Cognition, 87,* B79–B86.

Statement of Authorship – Eigenständigkeitserklärung

I declare that this dissertation has been composed by myself, and describes my own work. No other person's work has been used without due acknowledgement in the main text of the dissertation. Material from the published or unpublished work of others, which is referred to in the dissertation, is credited to the author in the text.

Hiermit bestätige ich, dass ich die vorliegende Dissertation selbständig verfasst und keine anderen als die angegebenen Hilfsmittel benutzt habe. Die Stellen der Arbeit, die dem Wortlaut oder dem Sinn nach anderen Werken (dazu zählen auch Internetquellen) entnommen sind, wurden unter Angabe der Quelle kenntlich gemacht.

Wolfsburg, 15.04.2014

Gabriele Paschek