COGNITIVE SCIENCE
A Multidisciplinary Journal

Cognitive Science 36 (2012) 359–372

ISSN: 0364-0213 print / 1551-6709 online
DOI: 10.1111/j.1551-6709.2011.01199.x

Handedness Shapes Children's Abstract Concepts

Daniel Casasanto,[a,b,c] Tania Henetz[d]

[a]*Neurobiology of Language Department, Max Planck Institute for Psycholinguistics*
[b]*Donders Institute for Brain, Cognition, and Behaviour, Nijmegen, Radboud University*
[c]*Department of Psychology, New School for Social Research*
[d]*Department of Psychology, Stanford University*

Received 27 June 2010; received in revised form 20 March 2011; accepted 30 March 2011

Abstract

Can children's handedness influence how they represent abstract concepts like *kindness* and *intelligence*? Here we show that from an early age, right-handers associate rightward space more strongly with positive ideas and leftward space with negative ideas, but the opposite is true for left-handers. In one experiment, children indicated where on a diagram a preferred toy and a dispreferred toy should go. Right-handers tended to assign the preferred toy to a box on the right and the dispreferred toy to a box on the left. Left-handers showed the opposite pattern. In a second experiment, children judged which of two cartoon animals looked smarter (or dumber) or nicer (or meaner). Right-handers attributed more positive qualities to animals on the right, but left-handers to animals on the left. These contrasting associations between space and valence cannot be explained by exposure to language or cultural conventions, which consistently link *right* with *good*. Rather, right- and left-handers implicitly associated positive valence more strongly with the side of space on which they can act more fluently with their dominant hands. Results support the *body-specificity hypothesis* (Casasanto, 2009), showing that children with different kinds of bodies think differently in corresponding ways.

Keywords: Cognitive development; Concepts; Embodied cognition; Emotional valence; Handedness; Metaphor; Space

How do children think about abstract ideas like *goodness*, *kindness*, or *intelligence*? Adults appear to mentally represent ideas that carry positive or negative emotional valence, in part, via spatial metaphors. Metaphors in language associate good things with *up* and bad things with *down* (e.g., spirits can *soar*; hopes can *plummet*; students can be *top-notch* or *rock-bottom*;

Correspondence should be sent to Daniel Casasanto, Department of Psychology, The New School for Social Research, 80 Fifth Avenue, 7th Floor, New York, NY 10011. E-mail: casasanto@alum.mit.edu

Gibbs, 1994; Lakoff & Johnson, 1980; Lakoff & Johnson, 1999). These linguistic metaphors correspond to mental metaphors: non-linguistic associative mappings from the concrete source domain of space, which we can experience through physical interactions with the environment, to the relatively abstract target domain of emotional valence, which we can only experience through introspection or interoception (Brookshire, Ivry, & Casasanto, 2010; Casasanto, 2009; Casasanto & Dijkstra, 2010; Crawford, Margolies, Drake, & Murphy, 2006; Meier & Robinson, 2004; Riskind & Gotay, 1982; Stepper & Strack, 1993).

In addition to associating valence with vertical space, adults also implicitly associate positive and negative ideas with left–right space—but not always as patterns in language suggest they should. Rather, adults' conceptualizations of abstract qualities like *goodness* and *honesty* appear to be *body-specific* (Casasanto, 2009). Whether judging which of two products to buy, which of two job applicants to hire, or which alien creature looks more trustworthy, right-handers tend to prefer the stimulus found on their right side but left-handers tend to prefer the one on their left. This pattern persists even when people make judgments orally, without using their hands to respond (Casasanto, 2009; Casasanto & Chrysikou, 2011).

Beyond explicit judgments in the laboratory, links between valence and left–right space can also be observed in spontaneous gestures during speech. The final debates of the 2004 and 2008 U.S. presidential elections involved two right-handers (Kerry, Bush) and two left-handers (Obama, McCain). In both of the right-handed candidates, right-hand gestures were associated more strongly with positive-valence speech and left-hand gestures with negative-valence speech, but the opposite pattern was found in both left-handed candidates (Casasanto & Jasmin, 2010).

Overall, these results cannot be predicted or explained based on conventions in language and culture, which consistently associate good with right (e.g., *my right-hand man*) and bad with left (e.g., *two left feet*). Rather, results support the *body-specificity hypothesis* (Casasanto, 2009; Casasanto & Chrysikou, 2011; Casasanto & Jasmin, 2010; Willems, Toni, Hagoort, & Casasanto, 2009; Willems, Hagoort, & Casasanto, 2010), showing that people with different kinds of bodies think differently in corresponding ways, even about highly abstract ideas. In particular, people implicitly associate good things with the side of space on which they can interact with the physical environment more fluently using their dominant hand (Casasanto, 2009; Casasanto & Jasmin, 2010). This association of dominant with good converges with a broader pattern of results linking perceptual and motor fluency with preference: People tend to like things that are easy to perceive and interact with (Beilock & Holt, 2007; Oppenheimer, 2008; Ping, Dhillon, & Beilock, 2009; Reber, Winkielman, & Schwarz, 1998).

How do body-specific mental metaphors arise, and when do they start to influence people's preference judgments? The goal of the present study was to determine whether right- and left-handed children have implicit associations between space and valence similar to those found in adults, and whether these mappings change as handedness stabilizes. Children's handedness often goes through cyclic changes during early development. Although reports vary, there is some consensus that handedness stabilizes at around 8 years of age (Corballis & Beale, 1976; Gesell & Ames, 1947). We tested 5- to 10-year-old children in order to examine space-valence mappings on either side of this stabilization point.

Tasks used previously in adults were adapted for kindergarten and elementary school-aged children. In Experiment 1, children performed an explicit diagram task, indicating into which of two boxes (on the left and right of a page) they would put their preferred and dispreferred toys. In Experiment 2, the spatial component of the task was more implicit. We asked children to attribute good and bad qualities (i.e., which one is *nicer*, *meaner*, *smarter*, or *dumber*) to cartoon animals on the right and left side of a page, so that we could determine whether the animals' incidental spatial location influenced children's judgments about them.

We considered several possible outcomes. On the first (and least informative) possibility, children could show no systematic preference for the right or left. This would be consistent with the striking paucity of evidence for implicit spatial metaphors in children outside of the domains of *time* (Casasanto, Fotakopoulou, & Boroditsky, 2010; Mori, Kitagawa, & Tadang, 1974; Piaget, 1927/1969; Tversky, Kugelmass, & Winter, 1991) and *number* (Bryant & Squire, 2001; Piaget, 1941/1952).

Alternatively, children could show the good-is-right mapping encoded in language and culture, regardless of their handedness. This outcome would be consistent with a causal role for language in the development of metaphorical mappings. This would seem especially likely for children younger than 8 years old whose handedness may still be labile. However, even if all younger children tend to show language-related mental metaphors, left-handed children must at some point start spatializing positive and negative concepts like left-handed adults. This raises the possibility that our younger group (5- to 7-year-old) could show the language-based pattern and our older group (8- to 10-year-old) the body-specific pattern, based on their more stable handedness or greater experience with asymmetric motor tasks like writing.

Finally, both young and old children could show the body-specific pattern found in adults' implicit judgments. This outcome would suggest either that body-specific mental metaphors are ''hardwired'' differently in right- and left-handers and their direction is experience independent, or that the degree of handedness children express by about age 5 is sufficient to produce experience-based mappings from their dominant and non-dominant sides of space to ideas with positive and negative emotional valence.

1. Experiment 1: Explicit spatialization of good and bad objects

Experiment 1 used a diagram task to test whether children associate toys they like and dislike with particular locations in left–right space. Children saw a pair of boxes on the left and right side of a drawing. They were asked to imagine a toy that they liked and a toy that they did not like, and then to indicate which box they would put each of the toys into.

1.1. Methods

1.1.1. Participants

A total of 119 children attending public school in California participated. Data from two ambidextrous children were excluded because their performance was not relevant to our comparison between right- and left-handers. A third child with documented learning disabilities was allowed to participate in the task but was also excluded from analyses. The remaining 116 children (64 female; $M = 7.5$ years, $SD = 1.2$ years) were divided into two groups, one above and below the age at which handedness has been reported to stabilize (approximately 8 years old; Corballis & Beale, 1976). The young group included 5- to 7-year-old children ($n = 52$; M = 6.4, SD = 0.7), and the old group 8- to 10-year-old children ($n = 64$; M = 8.4, SD = 0.6).

Children's handedness was assessed two ways: teacher report and observed behavior during the task (see below; 93 right-handers, 23 left-handers). Although handedness is continuously distributed throughout the population (Corballis & Beale, 1976), it was treated as a dichotomous variable here. Simple, dichotomous methods of classifying handedness have been shown to agree strongly with finer-grained measures (Coren, 1992). The proportion of right- and left-handers did not differ by age group (Fisher's exact test, $p > .1$).

1.1.2. Materials and procedure

Children saw a diagram of a five-shelf bookshelf with two identical toy boxes drawn on the right and left sides of the center shelf, approximately 8 cm apart. The diagram was displayed upright on the table, about 45 cm from the children. Three novelty pencils were used as ''pointers'' for the children to indicate their responses non-verbally.

The children completed the diagram task individually, after providing verbal assent. They sat at a table on either the left or the right side of the experimenter (location relative to experimenter was counterbalanced). Before viewing the diagram, the children were told they would answer some questions by pointing to parts of a picture with a ''special pointer.'' To determine the child's handedness, the experimenter let the children choose one of three novelty pencils to use as their pointer, and noted which hand they used to pick up the pencil and point with it. Only one child used a different hand for picking up the pencil and for pointing with it later. This child was independently identified by the teacher as ambidextrous.

The children were asked to pretend that the bookshelf in the picture was in their home, and the boxes on the shelf were for putting away toys. Then they were told to think of *a toy they like to play with* and *a toy they do not like to play with*. When the children had both toys in mind, they were asked to point first to the box where they would put the toy they liked, and then to the box where they would put the toy they did not like (or vice versa, with the order of questions counterbalanced across participants). The experimenter noted the children's responses and thanked them for participating.

1.2. Results and discussion

Handedness was a significant predictor of whether children placed the preferred toy in the box on the right and the dispreferred toy in the box on the left (or vice versa), according to a repeated measures binary logistic regression (valence × handedness interaction: Wald $\chi^2 = 8.44$, df = 1, $p = .004$; OR = 30.5; 95% CI = 1.3–305.8; Fig. 1a). Children were about 30 times more likely to assign the preferred toy to the box on their dominant side and the

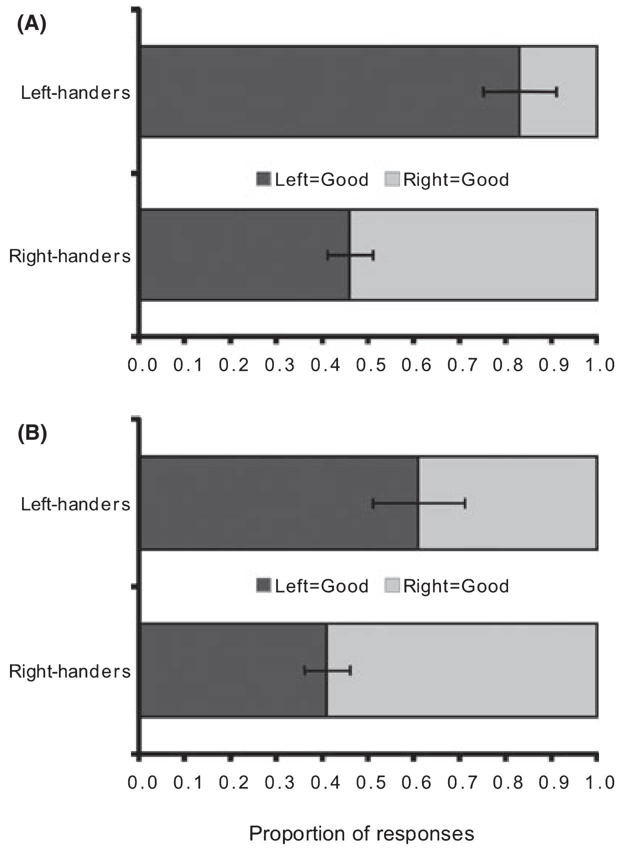

Fig. 1. Results of Experiments 1 and 2. 1a: Proportion of responses where right- and left-handed children placed a preferred toy in the box on the left (dark bar) and the right (light bar), and the dispreferred toy in the other box. 1b: Proportion of responses where right- and left-handed children attributed positive qualities (*niceness* and *intelligence*) to the animal of the left (dark bar) and the right (light bar), and negative qualities to the other animal. Error bars indicate standard error of the mean.

dispreferred toy to the box on their non-dominant side than vice versa. Overall, a significant majority of left-handers (83%) assigned the good toy to the box on the left (38 left = good vs. 8 right = good; sign test, $p = .0001$), whereas a non-significant majority of right-handers (54%) assigned it to the box on the right (86 left = good vs. 100 right = good; $p = .34$).

A similar pattern was found in both the young (5- to 7-year-old) and old (8- to 10-year-old) groups; there was no effect of age on the relationship between handedness and box selection, by repeated measures binary logistic regression ($p = .58$). Additional analyses assessed whether factors irrelevant to our question of interest influenced results. By repeated measures binary logistic regression, there was no interaction of handedness with question order (good or bad toy first), experimenter location (right- or left- side of child), or gender on box selection (All *p*s > corrected alpha of .01).

A further post hoc analysis compared the proportion of ‘‘dominant side is good’’ responses between right- and left-handers, and revealed that the body-specific pattern was stronger in left-handers (Wald $\chi^2 = 5.71$, df = 1, $p = .02$; OR = 4.1; 95% CI = 1.3–12.9). Although this difference was not predicted, it is consistent with trends seen in previous studies in adults (Casasanto, 2009; Casasanto & Jasmin, 2010).

In summary, both younger and older children showed a body-specific pattern of responses. Right-handers tended to place the preferred toy in the right box and the dispreferred toy in the left box, but left-handers showed the opposite pattern. As the order in which children were asked to spatialize the good and bad toys was counterbalanced, this pattern cannot be explained as a simple motor preference to respond on one's dominant side first; About half of the children were asked to first indicate where they would put their *dispreferred* toy. Therefore, they had to point to their *non-dominant* side first in order to respond as predicted by the body-specificity hypothesis.

2. Experiment 2: Implicit spatialization of good and bad qualities

In Experiment 1, why did children indicate the toys they liked should go on their dominant side and the toys they did not like on their non-dominant side? On a skeptical interpretation of these results, perhaps the children were taking the diagram task literally and placing the good toys in the boxes where they could have reached them most conveniently if the shelves in the depiction had been real. That is, perhaps children were computing the motor affordances of the shelves in the diagram (taking their own handedness into account) and positioning the toys accordingly. This would be interesting with respect to proposals that link motor affordances with preference (e.g., Beilock & Holt, 2007), but it would not necessarily support the claim that children mentally represent good and bad things, in part, via implicit associations with left–right space. It could merely mean that children were being practical.

To further test whether children have implicit associations between space and valence, in Experiment 2 we used a questionnaire task in which children judged abstract qualities of the target items. Participants saw pairs of cartoon animals on the right and left of a page and judged which animal was nicer (or meaner) or smarter (or dumber). Unlike toys, niceness and smartness cannot have any physical location, so there were no relevant affordances to compute. The judgment was non-spatial, and the spatial location of the target items was incidental. Does seeing an animal on the right or left side of a page cause children to judge it more favorably, and does the effect of the animal's incidental spatial location vary with handedness?

2.1. Methods

2.1.1. Participants

A total of 126 children participated in Experiment 2. This included the 119 children who performed Experiment 2 a few minutes after participating in Experiment 1, plus seven additional children. Data were excluded for two children who were ambidextrous, one who had documented learning disabilities, and four whose responses were ambiguous. The remaining

119 children (65 female; M = 7.4 years, SD = 1.3 years) were divided into age groups (young n = 59; M = 6.2, SD = 0.8; old n = 60; M = 8.5, SD = 0.7) and their handedness was determined according to the criteria used in Experiment 1 (96 right-handers, 23 left-handers). The proportion of right- and left-handers did not differ by age group (Fisher's exact test, p = .25).

2.1.2. Materials and procedure

Pictures of cartoon animals were presented in pairs, one pair at a time, with one animal on the right and the other on the left side of the page, approximately 8 cm apart. Pictures were displayed upright approximately 45 cm away from the child. One picture showed two birds (one green, one blue) and the other two rabbits (one yellow, one pink), facing forward. The order of animal presentation (birds then rabbits or vice versa) and the right or left placement of the differently colored animals was counterbalanced across participants.

As in Experiment 1, the children sat at a table next to the experimenter on the left or right, with their location counterbalanced. Before showing the first picture, the experimenter explained that she was going to ask some questions about animals. She told the children to give their answers by pointing to the diagrams, and she let them choose a novelty pencil to use as a pointer.

The children were asked to make judgments about the animals' friendliness and intelligence. Each question was framed either positively (e.g., ''Which animal is nicer/smarter?'') or negatively (e.g., ''Which animal is meaner/dumber?''). The order of the judgments (intelligence, friendliness) and order of the positively and negatively worded questions (positive first, negative first) were counterbalanced across participants. Children made a total of two judgments each, one for each diagram. The experimenter noted the children's response and thanked them for their participation.

2.2. Results and discussion

2.2.1. Results of Experiment 2

Handedness was a significant predictor of whether children assigned more positive qualities to animals on the right and more negative qualities to animals on the left (or vice versa), according to a repeated measures binary logistic regression (Wald χ^2 = 4.48, df = 1, p = .03; OR = 4.5; 95% CI = 1.1–18.3; Fig. 1b). The odds that children would judge the animals' abstract qualities as predicted by their own handedness were about 5 to 1. Among left-handers, a non-significant majority (61%) attributed more positive qualities to the animal on the left (28 left = good vs. 18 right = good; Wald χ^2 = 1.31, df = 1, *ns*), and a significant majority of right-handers (59%) attributed more positive qualities to the animal on the right (78 left = good vs. 114 right = good; Wald χ^2 = 8.15, df = 1, p = .004; OR = 2.12; 95% CI = 1.27–3.55).

A similar pattern was found in both the young (5- to 7-year-old) and old (8- to 10-year-old) groups; there was no effect of age on the relationship between handedness and box selection, by repeated measures binary logistic regression (p = .50). In control analyses, there was no interaction of handedness with question order (good or bad animal first), color of animal (e.g., yellow, pink), abstract quality (niceness or intelligence), experimenter location (right- or left- side of child), or gender on animal selection (all *p*s > corrected alpha of .01), ruling out the influence of these factors, which were irrelevant to our question of interest. The proportion of ''dominant side is good'' responses was slightly greater in left-handers than right-handers, but this difference was not significant (p = .86).

Results of Experiment 2 corroborate those of Experiment 1. The right-left location of the cartoon animals influenced participants' judgments of their abstract ''personal'' qualities—and influenced judgments in right- and left-handers differently. This was true even though spatial location was irrelevant to the judgments. In principle, there could have been inherent differences between animals within a pair (i.e., one animal might have simply looked nicer or smarter than the other), but due to counterbalancing, such differences could not account for the body-specific pattern of responses we find.

2.2.2. *Combined results of Experiments 1 and 2*

In a final set of analyses, data from Experiments 1 and 2 were combined in a repeated measures binary logistic regression to assess how strongly children's choices depended on the interaction between valence and handedness overall. Right- and left-handers were over 10 times more likely to associate positive things with their dominant side and negative things with their non-dominant side than vice versa (Wald χ^2 = 14.88, df = 1 p = .0001; OR = 10.8; 95% CI = 3.2–36.0). This association was significant in each handedness group considered separately, revealing body-specific mappings between space and valence both in left-handers (Wald χ^2 = 10.44, df = 1, p = .001, OR = 6.3; 95% CI = 3.0–19.4) and in right-handers (Wald χ^2 = 5.31, df = 1, p = .02, OR = 1.69; 95% CI = 1.1–2.7). The proportion of ''dominant side is good'' responses was greater for left-handers than right-handers (Wald χ^2 = 4.65, df = 1, p = .03; OR = 1.94; 95% CI = 1.1–3.6; see Casasanto (2009) for discussion).

3. General discussion

Two experiments in 5- to 10-year-old children revealed associations between horizontal space and concepts with positive and negative emotional valence. Children implicitly associated positive ideas more strongly with their dominant side and negative ideas with their non-dominant side. When making judgments about *preference* (preferred toy, dispreferred toy), right-handers tended to assign the good toy to the right side of a diagram and the bad toy to the left side, whereas the opposite pattern was found in left-handers. When making judgments about *intelligence* (smarter animal, dumber animal) and *kindness* (nicer animal, meaner animal), right-handers attributed positive qualities more often to cartoon animals they saw on the right side of a page, but left-handers to animals they saw on the left. These patterns cannot be explained by the order in which children made positive and negative judgments, the polarity of the questions they were asked, the side of the diagram that was most convenient for them to reach, or by other irrelevant factors such as the child's gender or their location relative to the experimenter. Rather, these data suggest that children represent ideas with emotional valence in part metaphorically, in terms of body-specific associative mappings from horizontal space.

3.1. Distinguishing influences of language, culture, and body on mental representation

These data closely resemble patterns of judgments in right- and left-handed adults and demonstrate that, from an early age, people's abstract concepts are shaped by the particulars of their bodies (Casasanto, 2009; Casasanto & Jasmin, 2010). In principle, the good-is-right mental metaphor in right-handers could result either from correlations in linguistic and cultural experience *or* from correlations in bodily experience—or from some combination of these sources. But the good-is-left mental metaphor in left-handers cannot be explained by linguistic and cultural experience: There do not appear to be any linguistic or cultural conventions that unambiguously associate ''good'' with ''left'' (and if there are any, they are greatly outnumbered by idioms that associate ''good'' with ''right''). Thus, the left-handed children implicitly associated good with left *in spite of* everything they learn from conventions in adults' language and culture.

These children were tested in the United States, where ''left'' is conventionally associated with clumsiness, but not necessarily with evil or filth, as in some other cultures. It remains an open question whether left-handers in cultures with stronger left-hand taboos (e.g., Ghananian culture, see Kita & Essegbey, 2001) would still show an implicit good-is-left mapping or whether body-specific mappings might be modulated by culture-specific biases.

3.2. Does motor experience give rise to mental metaphors?

Why do children's implicit associations between space and valence vary with handedness? We propose that implicit associations are formed as children interact with their physical environment more fluently with their dominant hand and less fluently with their non-dominant hand: Dominant is fluent, and fluent is good (e.g., Beilock & Holt, 2007; Casasanto, 2009; Oppenheimer, 2008; Reber et al., 1998). In support of this proposal, the data we report here show a correlation between motor experience and space-valence mappings.

Does motor fluency play a *causal role* in determining the direction of mental metaphors from space to valence? This question has been addressed in adults whose manual motor fluency was changed due to either long-term or short-term handicapping of the dominant hand. One experiment tested space-valence mappings in unilateral stroke patients with hemiparesis (weakness or paralysis) on either their right or left side. Although all patients were right-handed prior to brain injury, the patients whose left side could be used more fluently post-stroke showed a ''good-is-left'' association, like natural left-handers (Casasanto & Chrysikou, 2011).

In another experiment, right-handers participated in a two-part training task. For the training phase they performed a test of bimanual coordination, symmetrically arranging dominoes on a tabletop. On one hand they wore a bulky ski glove, with the other ski glove dangling inconveniently from the wrist of the gloved hand. For about half of the participants, wearing the glove on their left hand preserved their natural right-handedness. For the other half of the participants, wearing the glove on their right hand turned them transiently ''left-handed,'' reversing the normal relationship between motor fluency and their left and right sides of space. After training, participants removed the glove and performed a series of ostensibly unrelated questionnaires, one of which tested associations between space and valence (similar to Experiment 1 in the present study). Participants who had been assigned to wear the glove on their left hand associated good things with the right side of space, but those who had worn the glove on their right (normally dominant) hand associated good things with the left side of space. This was true even though there was no manual motor component to the test, eliminating trivial forms of transfer from the training phase to the test phase. Turning right-handed participants into functional left-handers temporarily reversed their usual preference judgments (Casasanto & Chrysikou, 2011).

These experiments demonstrate a causal relationship between motor experience and the spatial mapping of positive and negative concepts. This does not rule out the possibility that innate neurobiological factors could also contribute to the body-specific mappings observed in natural right- and left-handed adults and children. But the fact that right-handers' judgments *reversed* after long- or short-term changes in motor fluency indicates that motor experience is sufficient to determine the direction of space-valence associations, and even to temporarily overwhelm any innate predisposition there may be to associate ''good'' with one's naturally dominant side.

3.3. In what sense are children's judgments ''embodied''?

In what sense are the mental representations that children formed when performing these tasks ''embodied'' (Barsalou, 1999)? We conclude that right- and left-handers formed systematically different mental representations, which varied as a function of the bodily attribute of handedness. On the basis of the adult data reviewed above, we infer that representations differed not due to the mere fact of being genetically right- or left-handed but also due to the habit of performing fluent and relatively disfluent actions with the dominant and non-dominant hands. Therefore, children's mental representations are embodied insomuch as they depend in part on the particulars of their bodies, and presumably on the particulars of their habitual bodily interactions with the environment—a kind of ''diachronic embodiment.''

But what about ''synchronic embodiment''? Are representations of positive and negative ideas instantiated online, in part, via modality-specific mental simulations in brain areas that subserve motor planning or motor execution? In Experiment 1, it seems plausible that children mentally simulated placing toys on their dominant and non-dominant side of the shelves (perhaps implicitly) and assigned the good toy to the side that would afford more fluent placement if the shelves were real (e.g., Ping et al., 2009). But this sort of account seems less plausible in Experiment 2: What motor actions (real or simulated) would be implicitly and prepotently activated as the child evaluated the intelligence of the two cartoon animals? Unlike objects and locations, abstract qualities like intelligence and kindness do not afford specific motor actions. (Animals do afford motor actions, but it is not clear what afforded actions would be relevant for forming judgments of abstract qualities like intelligence.) As such, the present results may be difficult to explain in terms of implicit simulation of fluent and disfluent motor actions; they certainly do not entail an explanation based on motor simulation. Even if associations between space and valence are established through habits of motor action, it is possible that they are instantiated in a more abstract format that does not require activation of cortical motor areas.

Although the present data provide evidence for diachronic embodiment, they do not necessarily provide evidence for synchronic embodiment. That is, children's mental representations of positive and negative ideas appear to be shaped by their history of bodily interactions with the environment, but these mental representations may not be instantiated in modality-specific simulations. The extent to which body-specific space-valence mappings depend on online motor simulation remains a question for future research.

3.4. Are right-handers' concepts different from left-handers'?

Right- and left-handed children make contrasting judgments about preference, intelligence, and kindness. Does this mean that they have different *concepts* of preference, intelligence, and kindness, or is it only their judgments that differ? On our view, instantiating a concept is not a process of accessing a pre-formed package of knowledge; rather, it is process of activating stored information ad hoc (Casasanto & Lupyan, 2011). The representation that gets activated is co-determined by retrieval cues and the context in which they are encountered. In this study, the cues included the stimuli and the judgments the experimenter asked the child to make about them. The ''context'' included myriad aspects of the child's immediate physical and social environment, as well as the child's memory and experiential history. Some aspects of context are fleeting (e.g., the side of space on which someone encounters a given stimulus), but others are relatively stable (e.g., the particulars of the body someone uses to interact with their environment, and their history of using it in certain ways). On this view, the process of making a judgment about an attribute like ''kindness'' is continuous with the process of instantiating the concept ''kindness'' (see also Oppenheimer, 2008).

Some views of concepts preclude any interesting variability among individuals or groups, maintaining that concepts are mostly innate, atomic (i.e., having no internal structure), and therefore universal (Fodor, 1998). On other theories, concepts are richly structured and can change dramatically over time (Barsalou, 1982; Carey, 2009) but still have an essential core. On these theories, one might argue mental metaphors that link space with positively and negatively valenced concepts are not part of the concepts' cores; spatio-motor representations are *associated* with valenced concepts but are not *constitutive* of them. Therefore, right- and left-handers' core concepts are the same.

This stance raises the following questions. First, how do we know where a concept's core ends and its periphery begins? Second, what does it mean for right- and left-handers to have the ''same concepts'' if they use them differently, arriving at contrasting judgments of the same things? Turning to the first question, Wittgenstein (1953) famously exploded the notion of drawing a boundary around a concept and showed that it is impossible to identify necessary or sufficient features that could serve as the core of the concept *game*, or even of a more constrained-seeming concept like *number* (philosophical investigations [PI] §§66–100). These arguments also obtain for concepts like preference, intelligence, and kindness. What core features do all instances of *kindness* have in common (e.g., what unites *throwing someone a surprise party* with *euthanasia*, other than the fact that they can both be considered acts of kindness?) If there is no principled way to delineate a concept's core, then there is no way to establish whether a feature is partly constitutive of a concept or merely associated with it. This distinction dissolves.

Turning to the second question, in these same passages Wittgenstein argued that the meanings of words and the extensions of concepts are determined by the ways in which they are used (e.g., PI §§43, 68; see also Tomasello, 2003). Although it is not possible to define a concept or stipulate its constituents in the abstract, it is possible to instantiate a concept online such that it has certain properties in the mind of its user. Concepts with positive and negative valence tend to be instantiated differently in the minds of right- and left-handers, such that they include different associative links from space to valence. These differences lead right- and left-handers to arrive at predictably different conclusions when presented with the same objects. Therefore, on a usage-based theory, right- and left-handers have (i.e., tend to form) systematically different concepts.

4. Conclusions

Children implicitly associate ideas that carry positive and negative emotional valence with opposite sides of body-centered space. These associations differ between right- and left-handers. Right-handers tend to associate rightward space more strongly with positive ideas and leftward space with negative ideas, but the opposite is true in left-handers, for whom ''good'' is ''left.'' On the basis of bodily differences, right- and left-handed children tend to arrive at opposite judgments about the same objects in the world.

This pattern cannot be explained by idioms in language and culture, which consistently associate ''good'' with ''right.'' Rather, children's positive and negative associations reflect the way they usually interact with their physical environment, more fluently on their dominant side of space and less fluently on their non-dominant side. Results support the body-specificity hypothesis (Casasanto, 2009), showing that children with different bodily characteristics develop correspondingly different conceptual repertoires. *Bodily relativity* is one aspect of *experiential relativity* (Casasanto, forthcoming): People with systematically different linguistic, cultural, or bodily experiences come to think, feel, and make decisions differently, as a consequence.

Acknowledgments

This research was supported in part by an NRSA fellowship (F32MH072502), a grant from the Consejería de Innovación, Ciencia y Empresa, Junta de Andalucía and the European Regional Development Fund (P09-SEJ-4772), and a McDonnell Scholar Award to DC.

References

Barsalou, L. W. (1982). Context-independent and context-dependent information in concepts. *Memory & Cognition*, *10*, 82–93.

Barsalou, L. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*, 577–609.

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

Brookshire, G., Ivry, R., & Casasanto, D. (2010). Modulation of motor-meaning congruity effects for valenced words. In S. Ohlsson & R. Catrambone (Eds.), *Proceedings of the 32nd Annual Conference of the Cognitive Science Society* (pp. 1940–1945). Austin, TX: Cognitive Science Society.

Bryant, P., & Squire, S. (2001). Children's mathematics: Lost and found in space. In M. Gattis (Ed.), *Spatial schemas and abstract thought* (pp. 175–200). Cambridge, MA: MIT Press.

Carey, S. (2009). *The origin of concepts*. New York: Oxford University Press.

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General*, *138*(3), 351–367.

Casasanto, D., & Chrysikou, E. G. (2011). When Left is 'Right': Motor fluency shapes abstract concepts. *Psychological Science*, *22*(4), 419–422. DOI: 10.1177/0956797611401755.

Casasanto, D., & Dijkstra, K. (2010). Motor action and emotional memory. *Cognition*, *115*(1), 179–185.

Casasanto, D., Fotakopoulou, O., & Boroditsky, L. (2010). Space and time in the child's mind: Evidence for a cross-dimensional asymmetry. *Cognitive Science*, *34*, 387–405.

Casasanto, D. & Jasmine, K. (2010). Good and Bad in the Hands of Politicians: Spontaneous gestures during positve and negtive speech. *PLoS ONE*, *5*(7), e11805.

Casasanto, D., & Lupyan, G. (2011). Ad hoc cognition. In L. Carlson, C. Hoölscher & T. Shipley (Eds.), *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Corballis, M., & Beale, I. (1976). *Psychology of left and right*. Hillsdale, NJ: Erlbaum.

Coren, S. (1992). *The left-hander syndrome: The causes and consequences of left handedness*. New York: Random House.

Crawford, E. L., Margolies, S. M., Drake, J. T., & Murphy, M. E. (2006). Affect biases memory of location: Evidence for the spatial representation of affect. *Cognition & Emotion*, *20*(8), 1153–1169.

Fodor, J. A. (1998). *Concepts: Where cognitive science went wrong*. New York: Oxford University Press.

Gesell, A., & Ames, L. B. (1947). The development of handedness. *The Pedagogical Seminary and Journal of Genetic Psychology*, *70*, 155–175.

Gibbs, R. W. (1994). *The poetics of mind: Figurative thought, language, and understanding*. New York: Cambridge University Press.

Kita, S., & Essegbey, J. (2001). Pointing left in Ghana: How a taboo on the use of the left hand influences gestural practices. *Gesture*, *1*(1), 73–95.

Lakoff, G., & Johnson, M. (1980). The metaphorical structure of the human conceptual system. *Cognitive Science*, *4*, 195–208.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought*. Chicago: University of Chicago Press.

Meier, B. P., & Robinson, M. D. (2004). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science*, *15*(4), 243–247.

Mori, I., Kitagawa, O., & Tadang, N. (1974). The effect of language on a child's forming of spatio-temporal concept: On comparing Japanese and Thai children. *Science Education*, *58*(4), 519–522.

Oppenheimer, D. M. (2008). The secret life of fluency. *Trends in Cognitive Science*, *12*(6), 237–241.

Piaget, J. (1927/1969). *The child's conception of time*. New York: Ballantine.

Piaget, J. (1941/1952). *The child's conception of number*. London: Routledge and Kegan Paul.

Ping, R. M., Dhillon, S., & Beilock, S. L. (2009). Reach for what you like: The body's role in shaping preferences. *Emotion Review*, *1*(2), 140–150.

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science*, *9*(1), 45–48.

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

Stepper, S., & Strack, F. (1993). Proprioceptive determinants of emotional and nonemotional feelings. *Journal of Personality and Social Psychology*, *64*, 211–220.

Tomasello, M. (2003). *Constructing a language: A usage-based theory of language acquisition*. Boston: Harvard University Press.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*, 515–557.

Willems, R. M., Hagoort, P., & Casasanto, D. (2010). Body-specific representations of action verbs: Neural evidence from right- and left-handers. *Psychological Science*, *21*(1), 67–74.

Willems, R. M., Toni, I., Hagoort, P., & Casasanto, D. (2009). Body-specific motor imagery of hand actions: Neural evidence from right- and left-handers. *Frontiers in Human Neuroscience*, *3*(39), 1–9.

Wittgenstein, L. (1953). *Philosophical investigations* (G. E. M. Anscombe, Trans.). Oxford, England: Basil Blackwell.