Universiteit Utrecht

Left-right confusion

The influence of verbal labeling and strategy on left-right discrimination

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ABSTRACT

For navigation and orientation in daily life, knowing the difference between left and right is essential. Nevertheless, left-right confusion is a common phenomenon for healthy individuals. In previous studies, it is suggested that the problem lies within the labels assigned to spatial directions. This study examines verbal labeling as a cause of left-right confusion. Furthermore, a second question was added to this study, concerning strategy use and left-right confusion. One often reported strategy is holding the index finger and thumb in an angle of 90 degrees, forming an "L" shape on the left hand. The influence of this L-shape strategy on left-right confusion is investigated. An adapted version of the Bergen Left Right Discrimination test was used where in one part the participants were forced to use verbal labeling and in another part verbal labeling was prevented. The expectation was that less left-right confusion occurs in the non-verbal labeling conditions in comparison to the verbal labeling conditions. No significant differences were found, showing that no verbal labeling effect can be found in this study. For the strategy question, four conditions were created to examine whether the L-shape group was slower on a left-right decision task compared to people with other strategies when they are not able to form an L-shape with their hands (holding the palm of their hands upwards). No significant differences were found for this group, showing that hand position is not of more influence on individuals with an L-shape strategy. However, when looking at the total group, all participants were slower while holding the palm of their hands upwards, showing that hand position is of influence on left-right decisions.

1. INTRODUCTION

Humans are faced everyday with left-right decisions, which are important for navigation and orientation in the world around us. This left-right orientation requires distinguishing between the left and right side of our body and requires the ability to verbally identify the terms ‘left’ and ‘right’ (Mendoza & Foundas, 2007). Left-right orientation reaches an adult level around the age of 12 (Benton, 1959). However, mixing up left and right, left-right confusion (LRC), still frequently occurs after that age (Wolf 1973). This can be the result of neurological damage in the brain, for example following a cerebral vascular accident (Gold, Adair, Jacobs & Heilman, 1995), but LRC also occurs in healthy individuals. The latter is the main focus of this study.

So far, little is known about the cognitive processes or neural mechanisms that underlie LRC. The studies that exist are mainly focused on inter-individual differences like gender, handedness and educational background. In normal adults, studies based on self-report reveal a high rate of LRC. 42% of adults experience LRC regularly (Mcmonnies, 2009; Benton 1968). Even in high IQ populations, such as physicians (Wolf, 1973), university professors (Harris and Gitterman, 1978) and university students (Hannay, Ciaccia, Kerr & Barret, 1990; Ofte, 2002) people report experiencing LRC. These studies also found that women report experiencing more LRC than men.

There are multiple theories regarding why some people confuse left and right, but there is no consensus. One of these theories states that LRC is possibly the result of developmental problems that remain from childhood (Benton, 1959). Another states that the origin lies in the brain, and especially the bilateral symmetry between the two hemispheres (Hirnstein, Ocklenburg, Schneider & Hausmann, 2008). Lastly, another theory is that left-right confusion is the result of wrong verbal labeling of the words left- and right. Both behavioral research (Sholl & Egeth, 1981; Maki, 1979; Clark, 1973) and neurological research (Hirnstein, Bayer, Ellison & Hausmann, 2011; Seghier, 2013) indicates that verbal labeling affects LRC. Verbal labeling seems to provide a promising explanation for LRC. Nevertheless, it has not been studied in direct relation to LRC after the study of Sholl and Egeth in 1981. In addition, strategies and LRC have never been studied, even though many people report using strategies to determine left and right. As a result, little is currently known about the advantage of the use of strategies on left-right orientation or the disadvantage of using a wrong strategy or no strategy at all. This makes both themes important to study. The purpose of this study is twofold. First, it focuses on the possibility of verbal labeling being a cause of LRC. Second, the influence of using a strategy for determining left or right is investigated as well as the relationship between strategy and LRC.

1.1 Verbal labeling

The process of left-right orientation comprises two steps. First, there is a perceptual or spatial encoding process. For example, when someone asks you on which arm you usually wear your watch, you first have to encode on which side of the body the, for example, left arm is located. After the perceptual or spatial encoding process, the second step is to label that side with the word “left” or “right” (Farrell, 1979). This is called verbal labeling. Labels help us to orientate ourselves in the world around us. In the case of a word that is an onomatopoeia, like “hiccup” or “meow”, the word suggests its meaning. In most other cases, the label (or word) is arbitrary and does not reveal the meaning of the object. This is also the case with the verbal labels “right” and “left.” They are arbitrary and do not explain which spatial direction is indicated (Harley, 2010). In studies so far, it is assumed that LRC is the result of assigning a wrong verbal label and not the result of incorrect spatial encoding.

If LRC is solely the result of incorrect verbal labeling, it would be expected that this arbitrary verbal labeling would also cause problems for the words “up” and “down,” since those are directional as well and do not reveal their meaning. However, Maki (1979) found that the identification of right-left locations is more difficult than up-down locations. One of the possible explanations for this observation is based on the structural properties of the environment. The vertical dimension (up and down) contains an asymmetrical natural referent (like gravity) and a natural direction away from this (up). On the horizontal axis (left and right), the environment is often symmetrical, which can more easily create confusion (Clark, 1973). Sholl and Egeth (1981) presented the words left, right, up and down, and north, east, south and west in either a vertical or horizontal axis. They as well found that directional decisions are typically slower when the location is described by the words on the horizontal axis (east, west, right or left) than when described by the words on the vertical axis (north, south, up or down). The words were either presented on a vertical or horizontal location, but the conclusions remained the same independent of the axis they were presented on. This suggests that the influence of the labels of the words is stronger than the influence of the locations of the presented words. They concluded this is due to a verbal labeling effect. To investigate if this effect was also present when alternative labels were used, the compass letters N, E, S and W were replaced with the clock numerals 12, 3, 6 and 9. They found that there was no difference in reaction time for the axis the clock numerals were presented on. Even though the task required direction of attention to spatial location, clock numerals are not associated with directions like left and right. This shows that the verbal labeling effect depends on which type of verbal label is assigned to spatial directions and that left-right errors are not a result of incorrect spatial encoding, but the result of assigning a wrong label.

There also is neurological evidence that indicates verbal labeling errors as the cause of LRC. The angular gyrus (ANG) in the left parietal lobe has been studied to be involved in a number of language related processes, like semantic processing of language and the meaning of words. Besides that, it is also known for its involvement in spatial cognition like discriminating left from right (Seghier, 2012). LRC can be the result of a lesion in the left ANG. It has also been described as part of Gerstmann syndrome, a neurological disorder which typically appears after left parietal lesions. It is characterized by four major symptoms: acalculia, agraphia, finger agnosia and LRC (Gold, Adair, Jacobs & Heilman, 1995). A transcranial magnetic stimulation (TMS) study by Hirnstein, Bayer, Ellison and Hausmann (2011) also found links between the left ANG and LRC. TMS is a non-invasive magnetic method to activate or deactivate regions in the brain. After repetitive TMS on the left ANG the participants were not able to discriminate between left and right. This suggests that spatial information is integrated with the meaning of the words left and right in the left ANG and with that also assigning the labels "left" and "right" to a certain direction.

This study further investigates the involvement of verbal labeling in LRC by evaluating if LRC still exists when verbal labeling is prevented. This is because verbal labeling of the horizontal directional words, like left and right, can cause confusion because there is more symmetry in the horizontal direction, compared to the asymmetrical vertical directions. Since one of the explanations for left-right confusion is verbal labeling, it is possible that there will be less LRC when no verbal labeling is involved.

1.2 Strategy

The second part of this study will investigate which strategies people can use to discriminate left or right and how this can be of influence on LRC. Strategies have been the subject of studies regarding for example memory (Atay & Ozbulgan, 2007), although little is known about the involvement of strategy on LRC. However, there is some evidence that it might be of influence. In a study by Ofte (2002), LRC and educational background were analyzed. Medical students performed better on left-right discrimination tests compared to law and psychology students. Ofte explains this by stating that medical students are more experienced in visuospatial concepts and tests, including mental rotation. Therefore, this may have eased the use of strategy for these students. This suggests that the more experienced and sophisticated the used strategy is, the more LRC will decrease.

Focusing on what strategy is used in left-right discrimination might be important, since it can be of influence on left-right confusion. People use several strategies to discriminate left from right. A well-known strategy is holding the index finger and thumb at an angle of 90 degrees. On the left hand the index finger and thumb form an L-shape. Other strategies are for instance: determining the writing hand, thinking about where they wear a piece of jewelry or determining the side of the road they drive on. This study focuses on the effect of the L-shape strategy on LRC, and specifically what happens when the participants who normally use this strategy are prohibited from using it by putting their hand palm facing upwards. The L-shape strategy is a visual hand strategy, since the participants will look at their hand to check the L-shape. If they are prevented from doing so, they might try to still use the L-shape strategy by using mental imagery to mentally rotate their hand in the right position to see if there is an L-shape or not.

The link between mental rotation and left-right orientation has been the subject of a few studies. Mental rotation is the ability of your mind to rotate an object to match it to another object. In a study of Ratcliff (1979), patients with left and right cerebral lesions were asked to make left-right decisions during one task requiring mental rotation and another one that did not. Results showed that patients with right parietal lesions, compared to patients with left parietal lesions, made fewer errors in the upright position, where no mental rotation was required, while making more errors in the inverted position in which mental rotation was required. Therefore, Left-right orientation seems to be mediated by the visuospatial abilities of the right hemisphere for stimuli that require mental rotation.

Besides visuospatial functions, there is evidence for a link between motor imagery and activation in areas involved in motor execution and planning. In order to judge whether a picture of a hand is the right or left hand, mental rotation is used, for which the brain activation closely matches the operations required for the actual hand movements. Sekiyama (1982) demonstrated this using a laterality judgement task where participants had to judge whether a stimulus was a right or left hand. The reaction times varied, reflecting the time required to move one's own hand into congruence with the stimulus. Also Parsons (1987; 1995) confirmed that reaction times increase when the rotation angle of the stimulus is more complicated, thus requiring more time to mentally rotate. This effect is strongly influenced by the actual body position of the subject during the task, suggesting that subjects solve the task by using imagery of moving their own body. Siguru and Duhamel (2001) confirmed this hypothesis. They investigated if the position of the subject's own hands was of influence on the reaction time. They compared first and third person perspective of imagery to two different hand positions: resting their hands on one's lap or holding them behind their back. In first person imagery, the reaction time was higher when holding their hands on their back compared to holding them on one's lap. In third person imagery, the opposite effect was measured, suggesting that first person imagery involves motor action, while third person imagery involves non-motor mechanisms. The usage of motor imagery for left-right orientation is also confirmed by upper limb amputees. Their performance on a task involving left-right orientation is negatively affected by the side of the limb loss. This may be caused by a strategy in which the participants judged a stimulus by always comparing it to their present hand: a mismatch in shape implies that the stimulus must be the other hand (Nico *et al.*, 2004).

These existing studies link mental rotation with left-right orientation. It is clear that spatial information is important to left-right orientation when mental rotation is required. However, studies have never investigated the effect of strategies on left-right orientation, and especially strategies using spatial information, and left-right orientation.

1.3 Hypotheses

As described above, the aim of this study will be twofold. First the influence of verbal labeling on left-right confusion will be tested. To investigate this two tests will be created: One test in which there is verbal labeling of the words left and right necessary to determine left and right and one where this is not the case. It will be determined if there is any difference in reaction time between right-left labeling and no-right-left labeling. It is expected that the reaction time on the non-verbal labeling test will be better than on the verbal-labeling test, because there is often wrong verbal labeling when using left and right. When preventing the use of the words left and right, it is expected that there is less LRC and therefore the reaction time will be faster.

To test the second hypothesis regarding the L-shape strategy, there will also be a focus on left-right judgments and the reaction time. A left-right decision task will be created where in one part the participants have to hold their hands in hand palm-up positions and in the other part hand palm-down positions. The expectation is that participants who use the L-shape strategy, compared to participants with other strategies, will have a slower reaction time in discriminating left and right when the palms of their hands are facing upwards. This is hypothesized because people are not able to use the L-shape strategy without mental rotation of their hand to determine their left hand when their hands are positioned that way.

2. METHODS

2.1 Participants

A total of 33 healthy males (N= 10) and females (N=23) were tested in an age range between 19 and 28. The mean age was 22.80 years (SD=2.20) for males and 22.39 years (SD=2.45) for females. Two participants were excluded from the dataset because an essential part of the test data of was not saved correctly on the computer. One participant with an age above 35 years was excluded because spatial cognition declines after 35 years (Taillade et al., 2012). There were 31 right-handed participants and two left-handed (one male and one female), which was determined using the Edinburgh Handedness Inventory (Oldfield, 1971). Education level ranged from higher secondary education through university level.

All participants had normal or corrected vision and no history of neurological lesions. Participants were recruited through flyers and online advertisements at the University of Utrecht. Participation was voluntary and all participants provided written informed consent.

2.2 Procedure

The experiment took place in an examination room at the University of Utrecht. Participants were seated at a table in front of a monitor in a dimly lit room. Each test session began with an informed consent and general questionnaire. This was followed by the digitalized and adapted version of the *Bergen Left Right Discrimination Test* (Ofte & Hughdahl, 2002). The six conditions were given to each participant in a randomized order. During four of the conditions, a microphone placed 10 cm from the participant's mouth, was used for recording the verbal reaction times on the tasks. During the two other conditions, participants had to respond using a keyboard. During three of the conditions, the hands of the participants were tapped using a computerized tapping device (see *tactile stimulation).* During the test, the hands of the participants were either placed on the keyboard, or placed with the palm facing upwards or downwards, depending on the condition. Afterwards the participants completed a *left-right self-rating questionnaire* and *strategy questionnaire*. The total experiment took about an hour.

Except for the general questionnaire, all tasks were developed and presented in OpenSesame (Mathôt, Schreij & Theeuwes, 2012) on a computer. Prior to the experiment, the participants were not informed about the aim of the experiment. If desired, the participants could be informed at the end of the experiment. The researcher was present in the room during the test to answer questions and to record and note the answers of the participants.

The participants were instructed not to react to the stimulus with any other sound than the words "left," "right," "yes" or "no." Only reaction time was recorded by the microphone. In the case the microphone registered another sound, like "uhh," the next trial would start without a given answer. When this occurred, the participants were instructed to go to the next trial and the examiner made a note of the event. These responses were later excluded from the data.

2.3 Tasks and Stimuli

2.3.1 *General questionnaire and Edinburgh Handedness Inventory*

Information about gender, age and education was collected using a general questionnaire, which was given to the participant prior to the experimental session. The questionnaire also inquired if the participant had normal to corrected vision and if there was any history of neurological abnormalities.

Hand dominance was decided using a short version of the Edinburgh Handedness Inventory (Oldfield, 1971). This questionnaire contained ten items asking about daily activities (e.a. brushing your teeth) and which hand was preferably used during the activity. The participants could indicate the preferred hand with a + mark or using ++ when the preference was so strong that they would not use the other hand unless forced. This was later analyzed by adding up the amount of + for each hand and calculating a score. $LQ = ((\text{sum right hand} - \text{sum left hand})/(\text{sum right hand} + \text{sum left hand}))*100$. Finally it was decided if the participants were left handed ($LQ < -40$), right handed ($LQ > 40$) or ambidextrous ($-40 \leq LQ \leq 40$).

2.3.2 *Left-right self-rating, strategy and non-verbal questionnaire*

The aim of this questionnaire was to determine the strategies people use normally and during the experiment. It asked which of the given strategies the participant uses most often. The options were: determining the writing hand, L-shape strategy, thinking about a piece of jewelry, the side of the road to drive on, no strategy, or other strategies. Finally, the participants were asked whether they used a strategy during the experiment, and if so, which strategy was used to determine left or right. Next there were questions to determine how the participants rate themselves on left-right discrimination on a scale of one to ten. Lastly there was a question asking if the participants thought about the words 'left' and 'right' during the non-verbal conditions.

2.3.3 *Bergen Left-Right Discrimination Test*

A modified and digitalized version of the Bergen Left-Right Discrimination Test was used (Ofte & Hughdahl, 2002). This is originally a paper-and-pencil test, which provides a neuropsychological measure of making left-right decisions. The test consists of line drawings of human stickmen viewed from the front and from the back (figure 1). The front of the stickman is characterized by a line drawing of a face, while the back of the stickman can be recognized by hair at the back of the head. The shoulders are represented as a black triangle. Circles at the end of the stick-arm indicate the hands of the figure.

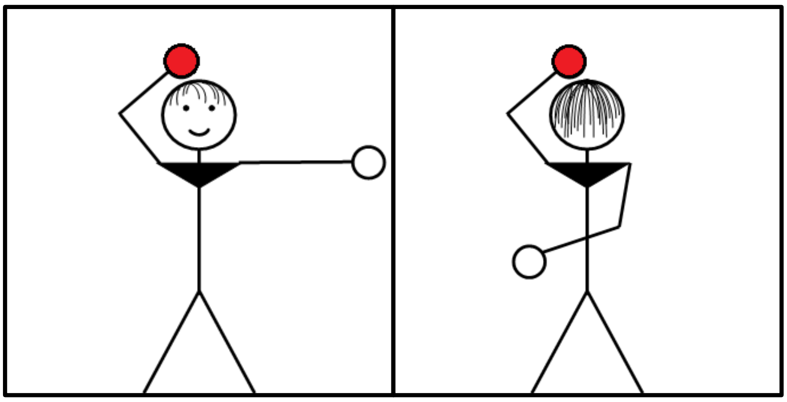

Figure 1: Example of human stickman from the front and back.

The participants were presented with three different arm positions; both arms crossing the body's vertical midline, only one arm crossing the vertical midline, or no arm crossing the vertical midline. One hand of the stickman was colored red. The participants had to identify if this was the right or left arm. In this study there were 60 trials in each condition. Half of these trials were human stick figures shown from the front, divided in 15 left arm figures and 15 right arm figures. In the other 30 trials, the stick figures were shown from the back, with 15 left arm figures and 15 right arm figures. The figures were given in a random order. The test started with a 500 milliseconds (ms) blank screen, followed by a 1000 ms fixation cross. After this, the image of the human stickman appeared. The participants were asked to give a response as fast as possible after the image appeared. The participants did this either by speaking in a microphone or by pressing a key on a keyboard, depending on the condition. After each response of the participant, a new trial started and the fixation cross reappeared.

2.3.4 Tactile stimulation

Tactile stimulation was delivered by metallic pins with a diameter of 2 mm. The stimuli were applied using computer controlled miniature solenoid tappers (MSTC3 M&E Solve, Rochester UK). The tappers were attached to either the top or the palm of both hands using medical tape. All taps had a duration of 5 ms and were given with an intensity that was above threshold but not discomforting.

2.4 Design

The test consisted of 6 different conditions (table 1). Two conditions tested verbal labeling, two tested non-verbal labeling and two tested for strategy. Two versions of the test were created in which the order of the conditions was presented differently. Before each condition started, a practice run occurred. This practice run consisted of ten practice trials.

Table 1: Overview of the six test conditions

Conditions	Measures	Output	Response	Hand position
1.	Verbal labeling and L-shape strategy	Microphone	"Left" or "Right"	Dorsal
2.	Verbal labeling	Keyboard	← or→ key	Dorsal
3.	Non-verbal labeling and L-shape strategy	Microphone	"Yes" or "No"	Dorsal (with tap)
4.	Non-verbal labeling	Keyboard	J or N key	Dorsal (with tap)
5	No-L-shape	Microphone	"Left" or "Right"	Ventral
6	No-L-shape	Microphone	"Yes" or "No"	Ventral

As can be seen in table 1, in the first verbal labeling condition (condition 1) the participant was sitting with the palm of his hand facing downwards (dorsal), the two index-fingers 20cm apart. The hand of the stick-figure that was colored red had to be verbally labeled "right" (*rechts* in Dutch) or "left" (*links* in Dutch). In the second verbal labeling condition (condition 2), instead of giving the answer in the microphone, the participant had to press the arrow buttons on the keyboard. The right arrow stood for "right" and was pressed with the right hand. The left arrow stood for "left" and was pressed with the left hand.

In the first non-verbal labeling condition (condition 3), one of the hands of the figure was again colored red. At the same time as the image appeared, the participants were tapped on either the right or the left hand. The participant had to determine if the colored hand on the figure and their own hand that was tapped were the same or different. They did this by saying "yes" (*ja* in Dutch) or "no" (*nee* in Dutch) in a microphone. After the participant had answered in the microphone, the next trial started. In the second non-verbal labeling condition (condition 4), instead of giving the answer in the microphone, the participant had to press either de j-key ("yes") with their right hand or the n-key ("no") with their left hand on the keyboard.

The first condition testing for strategy (condition 5) consisted of the same test as in the first verbal labeling condition (condition 1). The participant had to verbally indicate the hand of the stickman using the labels “left” and “right.” The only difference was that the participant’s hands were flat on the table with the palm of the hand facing upwards with a distance of 20 cm between the little fingers, thus making the L-shape strategy less effective. The second condition testing for strategy (condition 6) consisted of the same test as condition 4. The participants had to verbally answer in the microphone if there was a match between the hand that was tapped and the hand of the stick figure shown on the screen. The only difference was that the participant’s hands were flat on the table with the palm of the hand facing upwards, making the L-shape strategy less effective. In table 2 an overview can be found of which conditions are used to test the hypotheses.

Table 2: Overview of conditions used for testing hypothesis

Hypothesis	Conditions
1. Non-verbal labeling has a faster reaction time compared to the verbal labeling conditions	Verbal labeling: 1+2 Non-verbal labeling: 3+4
2. The reaction time on the L-shape conditions is faster than the reaction time on the no-L-shape conditions	L-shape: 1+3 No-L-shape: 5+6

2.5 Statistical Analyses

The first question of this study regards whether verbal labeling of the words left and right is of influence on left-right discrimination. Variables in this are output and response for a within subject 2 (microphone/keyboard) x 2 (left-right/yes-no) design. To measure the relation between these four variables, a repeated measures analysis of variance (ANOVA) is used. Expected is a higher reaction time for left-right compared to yes-no on both output conditions. A separate paired t-test analyses will be performed to analyze the difference between the left-right and yes-no conditions within the microphone and keyboard conditions.

To analyze whether hand position is of influence on participants with an L-shape strategy, a 2 x 2 x 2 mixed ANOVA is used. The two within subject variables, hand positions (ventral and dorsal) and response (yes-no and left-right) are compared to the between subject two strategy groups (L-shape strategy/other strategies). The L-shape participants are separated from the other strategy participants based on the answers on the *strategy questionnaire*. This test will reveal if hand position is of more influence on the L-shape participants than on the other strategy participants. This will be separated by microphone and by keyboard. Expected is a significant difference between the hand positions and the two strategy groups. The L-shape group should have a slower reaction time in the ventral hand position compared to the other strategy group. This will be followed by a Bonferroni corrected t-test, which will analyze the difference between left-right and yes-no for the ventral and dorsal hand positions.

To check for unintentional use of the words “left” and “right” during the yes-no conditions, the *left-right questionnaire* is analyzed using a chi-square goodness of fit test. The expectation is that most people have not thought about left-right during the yes-no conditions, and thought about left-right during the left-right conditions.

3. RESULTS

3.1 Verbal labeling and non-verbal labeling

Four conditions were created to test whether verbal labeling has an effect on reaction time. This was measured by using different output devices (keyboard or microphone) and letting the participants answer in different types of responses (yes-no or left-right). The descriptive statistics of these four conditions are shown in table 3.

Table 3: Mean (M) and standard deviations (SD) for condition 1, 2, 3 and 4 for output and response (N=33)

Condition	*M [ms]*	*SD [ms]*
1. Microphone LR	1109.99	382.32
2. Keyboard LR	930.71	247.40
3. Microphone YN	1087.81	352.17
4. Keyboard YN	1256.64	372.71

Output and response were examined using a 2 (microphone or keyboard) × 2 (yes-no or left-right) repeated measures ANOVA. The results are shown in table 4. This shows a significant main effect for response, $F(1,32)=15.98$, $P<0.00$. Participants show a statistically higher mean reaction time (RT) for the yes-no (YN) response in comparison to the left-right (LR) response. There is no main effect found for output, so there is no difference in RT between the use of the microphone or the keyboard.

An interaction effect is found for output × response, $F(1,32)=60.33$, $P<0.00$. This indicates that there is a difference in participants’ RT in between output and response. Looking at the interaction graph (figure 2), the interaction can be interpreted by stating that when participants are using the keyboard, their RT is higher when they have to respond using YN compared to when they have to respond using LR. This difference is not seen in RT when using the microphone.

Table 4: Main effects and interaction effect on repeated measures ANOVA for output and response (N=33)

	SS	*df*	*MS*	*F*	*P*	η^2
Output	900.56	1	900.56	.032	.859	.001
Response	761102.92	1	761102.92	15.98	.000*	.333
Output *Response	999727.65	1	999727.65	60.33	.000*	.653

* P=<0.05

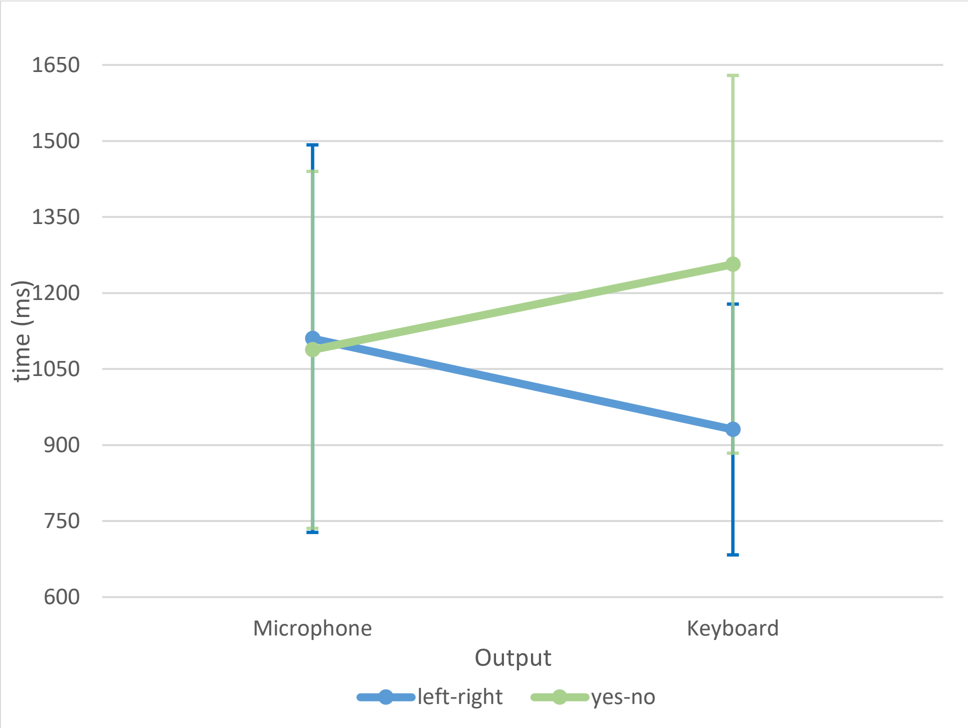

Figure 2: Interaction effect of output and response with standard deviation error bars.

A paired-samples t-test was used to compare RT of the LR and YN conditions. During the microphone conditions, participants were slightly faster using the words YN (M=1087.81, SD=352.17) compared to the using the words LR (M=1109.99, SD=382.32). This difference was not significant, t(32)=.48, P>0.05. For the keyboard conditions the participants using the YN words were slower (M=1256.64, SD=372.71) compared to using the words LR (M=930.71, SD=247.40). This difference was significant, t(32)=-7.74, P<0.05.

Table 5: Paired Sample t-test for LR and YN for microphone and keyboard conditions.

Output	*Response*	*N*	*M*	*SD*	*T*	*df*	*Sig.*
Microphone	LR	33	1109.99	382.32	.48	32	.633
	YN	33	1087.81	352.17			
Keyboard	LR	33	930.71	247.40	-7.74	32	.000*
	YN	33	1256.64	372.71			

* P=<0.05

3.2 Strategy Questionnaire

The *strategy questionnaire* determined whether the participants used a strategy. Based on the questionnaire, most participants (N=19) did not use a strategy. Most people who used a strategy determine left and right by using the L-shape strategy (N=7), followed by the writing hand (N=3) and a different strategy (N=3). Piece of jewelry (N=1) and side of the road (N=0) were the least used strategies. These results are also shown in table 6. Because condition 6 was later added during the testing phase, not all participants completed condition 6. For the ANOVA, described in paragraph 3.3, only the participants who participated on all L-shape conditions were used in the data analysis. This group is also shown in table 6.

Table 6: Strategies used by all participants and participants used in ANOVA in paragraph 3.3.

Strategy used	*N (all participants)*	N (*used for ANOVA*)
L-shape	7	5
Writing hand	3	3
Piece of jewelry	1	0
Side of the road	0	0
No strategy	19	10
Different strategy	3	0
Total	33	18

3.3 L-shape strategy and other strategies

To test whether hand position has an effect on reaction time for participants using the L-shape strategy during the LR and YN conditions, four conditions were used. This was measured by different hand positions (dorsal and ventral) and different responses (left-right and yes-no). Based on the *strategy questionnaire,* 5 participants were classified in the L-shape strategy group and 13 participants in the other strategy group. The means and standard deviations for these groups and total group can be found in table 7.

Table 7: Descriptive statistics of response and hand position for conditions 1, 2, 5 and 6 for L-shape strategy (N=5), other strategy (N=13) and total (N=18).

Condition	*Group*	*M [ms]*	*SD [ms]*
1. Dorsal LR	L-shape	919.77	137.78
	Other strategy	1130.61	429.18
	Total	1072.04	379.38
2. Dorsal YN	L-shape	937.13	198.18
	Other strategy	1090.57	442.66
	Total	1047.94	390.59
5. Ventral LR	L-shape	1039.31	158.90
	Other strategy	1211.30	410.62
	Total	1163.53	362.27
6. Ventral YN	L-shape	851.75	191.82
	No strategy	1101.96	503.48
	Total	1032.45	448.20

The two strategy groups were compared using a 2 (yes-no or left-right) × 2 (dorsal or ventral hand position) x 2 (L-shape strategy or other strategy) mixed ANOVA. There were no significant main effects for response or hand position, as can be seen in table 8. This means that participants who use the L-shape strategy have the same RT on tests that use the words left-right and yes-no as participants who use no strategy. There was an interaction effect for hand position and response, but not for hand position and response for the L-shape strategy group. This can be seen in figure 3 and 4.

Table 8: Repeated Measures ANOVA results for response and hand position (N=18)

	SS	*df*	*MS*	*F*	*P*	η^2
Response	92207.99	1	92207.99	1.95	.182	.109
Hand position	14388.70	1	14388.70	3.36	.086	.173
Response *strategy	67882.93	1	67882.93	11.49	.004*	.418
Hand position* response* L-shape strategy	16599.44	1	16599.44	2.81	.113	.149

*P<0.05

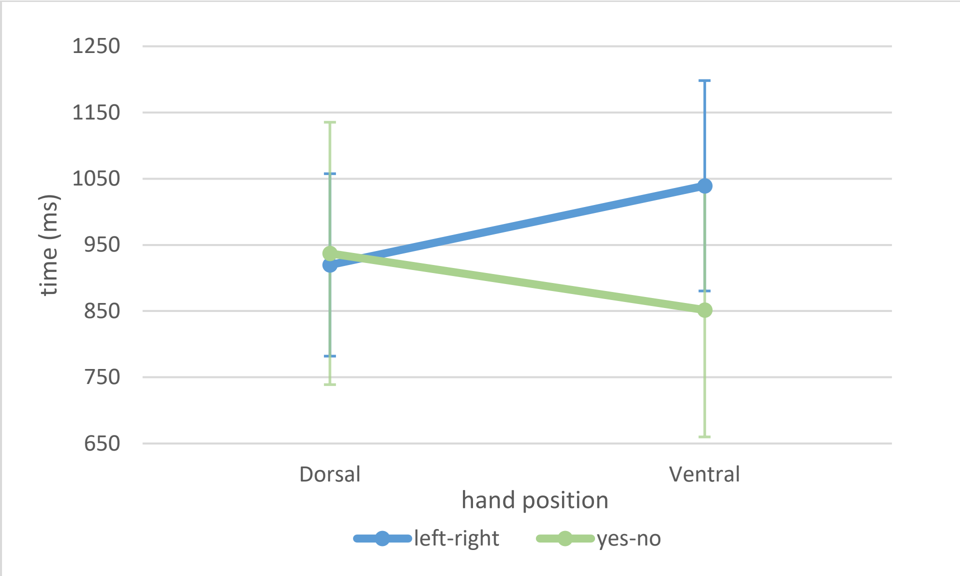

Figure 3: ANOVA results for hand position and output for L-shape strategy participants (N=5) with standard deviation error bars.

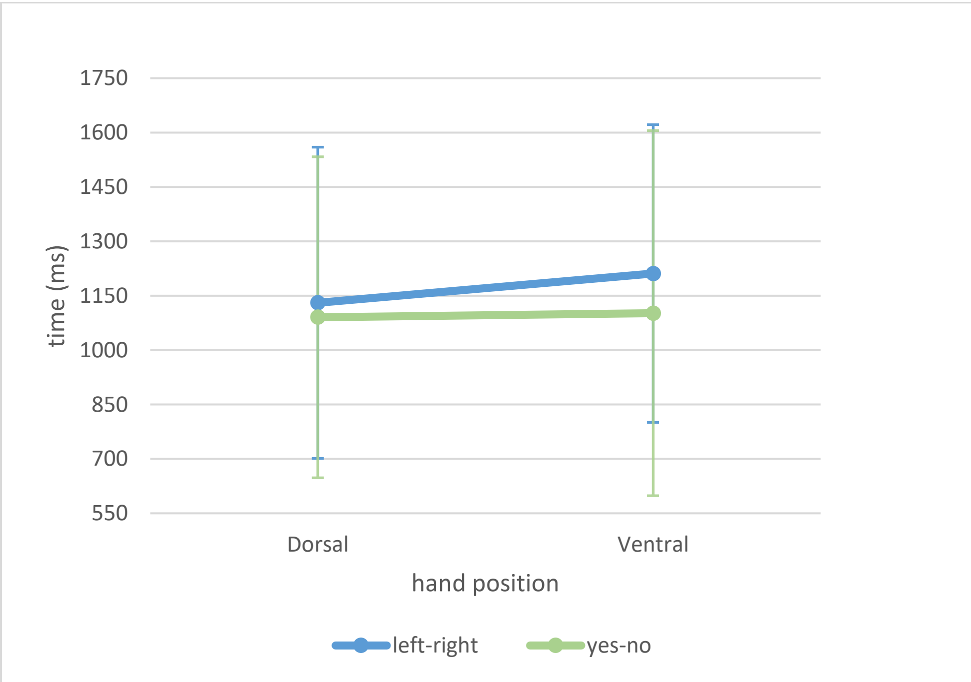

Figure 4: ANOVA results for hand position and output for other strategy participants (N=13) with standard deviation error bars.

Besides investigating the two strategy groups, another analysis was done for the total group. A 2 (dorsal and ventral) x 2 (LR and YN) repeated measures ANOVA was conducted on the total group. Looking at the total group, without separating the participants with an L-shape strategy, a main effect for hand position is found $F(1,17)=6.17$, $p=0.02$, as can be seen in table 9. Participants show a significant higher mean RT for the ventral hand position compared to the dorsal hand position. No main effect is found for response. There is a significant interaction effect between strategy and hand position, F(1,17)=7.88, p=0.01. This indicates that hand position has different effects on RT depending on which response is used. Looking at figure 5, the interaction graph shows that only in the LR condition participants have a higher RT when their hands are in a ventral position compared to a dorsal position. For the YN condition there is no difference in RT.

As can be seen in table 10, post hoc comparisons using a t-test with Bonferroni correction confirmed this. For the ventral hand position, the mean score for the LR conditions (M=1163.53, SD=85.39) was higher compared to the YN conditions (M=1032.46, SD=85.39). There was no significant difference for the dorsal hand position for the LR conditions (M=1072.04, SD=89.42) and YN conditions (M=1047.95, SD=92.06).

Table 9: Repeated Measures ANOVA results for response and strategy (N=18)

	SS	*df*	*MS*	*F*	*P*	η^2
Response	108348.20	1	108348.20	2.44	.14	.13
Hand position	25988.40	1	25988.40	6.17	.02*	.27
Response *hand position	51495.44	1	51495.44	7.88	.01*	.32

* P<0.05

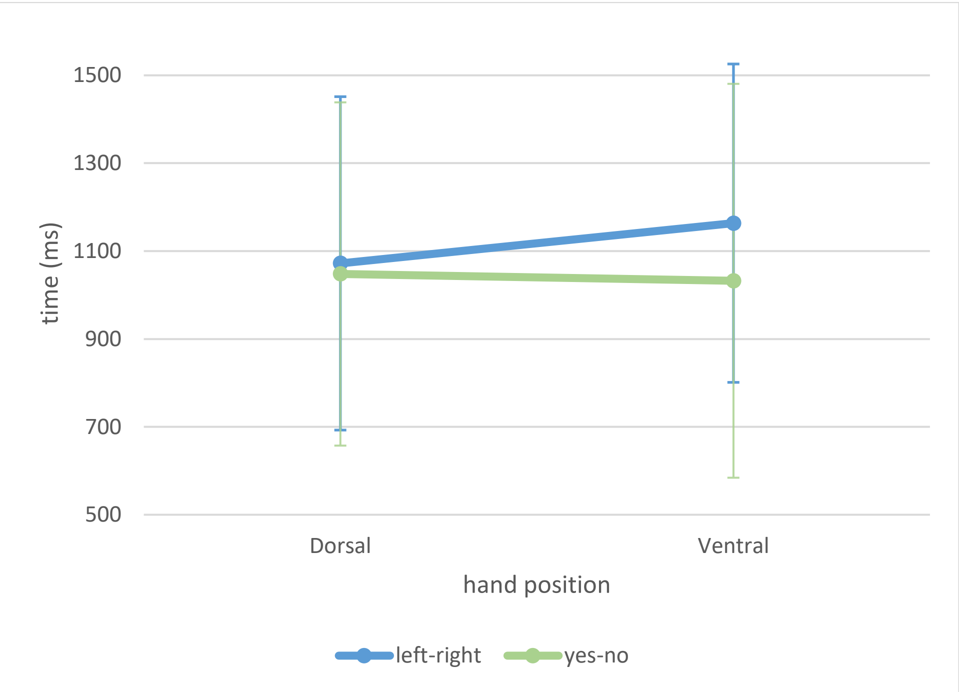

Figure 5: Interaction effect of response and hand position for all strategy groups with standard deviation error bars.

Table 10: Bonferroni corrected t-test for LR and YN for ventral and dorsal hand positions.

Hand position	*Response*	*N*	*Mean difference*	*Std. Error*	*Lower Bound*	*Upper Bound*	*Sig.*
Ventral	LR	18	131.07	60.16	-16.81	278.95	.044*
	YN	18	-131.07	60.16	-278.95	16.81	
Dorsal	LR	18	24.10	45.30	-87.25	135.45	.602
	YN	18	-24.10	45.30	-135.45	87.25	

* P=<0.05

3.4 Left-right questionnaire

To confirm if the main goal of the verbal labeling and non-verbal labeling conditions was met, the left-right questionnaire was used. It checked if participants were mentally using the words "left" or "right" during the YN and LR conditions. As shown in table 11 and 12, a chi-square goodness of fit test was used to determine whether, during the LR conditions, the amount participants that did think about the words left or right (Yes, N=25) was significantly different than the amount of participants that did not (No, N=8). There was a significant difference, $\chi2$ (1) = 8.758, P = 0.003, which means that more participants thought about the words left and right during the LR conditions than participants that did not.

The chi-square goodness of fit test was also used to determine if, during the YN conditions, the amount of participants thinking about left or right (Yes, N=11) was significantly different than the amount of people that did not (No, N=22). As shown in table 11 and 12, there was no significant difference, $\chi2$ (1) = 3.667, P > 0.05.

Table 11: Frequencies of participants thinking about left or right during LR and YN conditions

	LR		***YN***	
	Yes	*No*	*Yes*	*No*
Observed Frequency	*25*	*8*	*11*	*22*
Expected Frequency	*16.5*	*16.5*	*16.5*	*16.5*

Table 12: Chi square test for testing thoughts of left and right

	LR	***YN***
χ^2	8.758	3.667
Df	1	1
P	0.003	0.056

4. DISCUSSION

The purpose of this study was twofold. Verbal labeling is examined as a possible explanation for LRC, and it was investigated if strategy for determining left and right is of influence on LR decisions.

First, the theory was tested whether left-right confusion arises as a result of the use of the words “left” and “right.” This would be a verbal labeling problem. The *Bergen Left-Right Discrimination Test* was adapted in a way that participants had to use verbal labeling, using the words “left” and “right,” and in another part prevented them from using verbal labeling, using “yes” and “no.” The responses could be given in either the microphone or on the keyboard. It was expected that the reaction time of the non-verbal labeling conditions would be faster than on the verbal labeling conditions because verbal labeling may cause left-right confusion. This was based on the study of Sholl & Egeth (1981), who showed that left-right errors are the result of assigning a wrong label to spatial directions. However, this could not be confirmed by this study. The verbal labeling condition did not differ significantly from the non-verbal labeling condition when using the microphone. For the keyboard, the results were opposite from what was expected. The non-verbal labeling conditions were significantly slower than the verbal labeling conditions. This rejects the hypothesis that the non-verbal labeling conditions have a faster reaction time on a left-right decision task than the verbal labeling conditions.

A possible explanation for this is that it may be due to difficulties in using the J- and N-keys on the keyboard. The left- and right arrows are more frequently used and indicate a direction, while the J- and N-keys are not used as frequently. Participants had to determine the accurate key by looking at the keyboard during the test. Another limitation to this study was that one third of the participants revealed on the *left-right questionnaire* to have thought about the words “left” and “right” during the non-verbal labeling conditions. Even though this was not a significant difference from the people who did not, thus assuming the test YN conditions were accurate, it is still a large group. This might have been of influence in comparing the verbal labeling conditions to the non-verbal labeling conditions.

These results do not confirm that verbal labeling is a part of left-right confusion. This is consistent with a previous study by Hirnstein (2011), which also did not report a relation between verbal labeling and LRC. A consonant-vowel dichotic listening task was performed followed by a LRC self-rating questionnaire. Participants with a higher level of LRC made more mistakes on the task compared to participants with a lower level of LRC. Since the process of auditory information takes place at an earlier stage than verbal labeling, this suggests that LRC arises in the brain before verbal labeling is active. This rejects the process of verbal labeling as a possible cause in LRC. Correspondingly, in an earlier mentioned study from Gold, Adair, Jacobs & Heilman (1995), a patient with Gerstmann syndrome was described. One of the symptoms of Gerstmann syndrome is LRC. If the patient’s problem with LRC was primarily one of verbal labeling, naming errors would be expected while naming (left-right) body parts but no pointing errors. This was not the case. This as well indicates that LRC is not caused by wrong verbal labeling.

The second part of this study concerned the relation between the L-shape strategy and left-right confusion. Based on the *strategy questionnaire,* participants were classified in the L-shape strategy group and other strategy group. These two groups were compared on performance of an adapted version of the *Bergen left-right discrimination test* while holding their hands in dorsal and ventral positions. The ventral position was meant to make it more difficult for participants to use an L-shape strategy by putting the palm of their hands upwards so it would not form a visual L-shape. It was expected that participants using the L-shape strategy would be slower than participants using other or no strategies. This was based on several studies researching mental rotation, body position and reaction time (Parsons, 1987; Siguru & Duhamel, 2001; Sekiyama, 1982). It was expected that participants using the L-shape strategy would use mental rotation to rotate the hand from a ventral into a dorsal position to still be able to perform the L-shape strategy, which requires more time. However, this could not be confirmed in this study. There was no interaction found between hand position, response type and strategy. This rejects the hypothesis that individuals with the L-shape strategy are slower than individuals with other strategies when they hold their hand in the ventral position.

The results for the hand position task were different than expected. A possible explanation for this result may be due to the low number of L-shape participants in this study (only five participants were suitable to be tested). This large difference from the other strategy group could have been of influence on the results. Future research testing a larger sample of L-shape strategy participants may give a different result. Another explanation may be that there might not have been a difference between the two groups. When looking at the whole experimental group, all participants are slower when they have to perform a left-right orientation task with their hands in a ventral position. This includes not only the participants with an L-shape strategy, but also the other participants. This suggests that all participants, no matter their left-right orientation strategy, may use their body, and especially their hands, to determine left or right.

In this study was found that hand position does not play a significant role in the level of left-right confusion of people with an L-shape strategy compared to people with other strategies. This is in line with the earlier mentioned studies of Sekiyama (1982) and Parsons (1987), who demonstrated increased reaction times for the whole study group when moving one's own hand into congruence with the stimulus. Siguru and Duhamel (2001) also found increased reaction times when holding the hands on the back while answering questions about one's own hands. In another study by Funk, Brugger & Wilkening (2005), children and adults were tested on recognizing left and right hands in palm up and palm down positions, while also having the participants hold their own hands in palm up and palm down position. When adults hold their hands in palms-up posture or palms-down posture, they recognized palm view pictures at the same speed, while they were slower recognizing the back views when their own hands were in de palms-up posture. This suggests that the time taken for mental rotation may be dependent on the posture of a person's own hand. According to the previous mentioned studies and the current study, one's hand position is of influence on LRC for everybody, independent from the use of visual strategies.

In summary, the results of the verbal labeling task did not show a verbal labeling effect for LRC. This is not in line with the expected hypothesis of this study, but is in line with the study of Hirnstein (2011), who rejected the verbal labeling theory. It should be noted that there were some limitations to the method of this study, which might have been of influence. Thinking about left or right might not have been eliminated completely during the YN conditions. Further research is needed to fully eliminate left-right verbal labeling to make the verbal labeling effect visible for left-right confusion, like Sholl & Egeth (1981) found in their study. The hypothesis of a slower reaction time when having a ventral hand position was not found only for people with an L-shape strategy compared to people with other strategies. All participants were slower in discriminating left from right when they had to hold their hands palm up. This suggests that not only people who have a focus on their hands during left-right discrimination are slower; all people's reactions to left-right decisions are dependent on the posture of one's hand. Hand position is of influence in left-right decisions and the role of proprioception in left-right orientation should be studied more in the future to provide a more thorough understanding of LRC.

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6. APPENDIX

6.1 Questionnaires (in Dutch)

6.1.1 *General questionnaire (on computer)*

1. Geslacht (man/vrouw)

2. Leeftijd (in te vullen)

3. Wat is je hoogst afgeronde opleidingsniveau?

4. Heb je een goed/gecorrigeerd gezichtsvermogen?

5. Studentnummer (optioneel in verband met proefpersoon uren)

6.1.2 *Edinburgh Handedness Inventory (on computer)*

Geef aan met welke hand (links/rechts/beiden) je de volgende activiteiten zou doen:

- Schrijven
- Tekenen
- Gooien
- Knippen met een schaar
- Tanden Poetsen
- Een lepel gebruiken
- Een mes gebruiken (zonder vork)
- De bovenste hand bij het vasthouden van een bezem
- Een lucifer aansteken
- Een doos openmaken (deksel)

6.2.3 *Left-right self rating and strategy questionnaire (on paper)*

1. Heb je een speciale strategie gebruikt voor het oplossen van de taak met de poppetjes? Zo ja, wat voor strategie?

2. Welke van de onderstaande strategieën gebruik je wel eens om links en rechts te bepalen?

a. Nagaan wat de schrijfhand is; dit is links of rechts

b. Duim en wijsvinger in een hoek van 90 graden houden; bij de linkerhand vormt dit een “L” en bij de rechter hand niet (een omgekeerde “L”)

c. Een sieraad dragen aan een bepaalde hand.

d. Nagaan aan welke kant van de weg je rijdt (in Nederland is dit rechts).

e. Ik gebruik geen strategie. Ik weet gewoon wat links is en wat rechts.

f. Iets anders, namelijk (open vraag).

3. Welke van deze strategieën gebruikt je het <u>meest?</u>

a. Nagaan wat de schrijfhand is; dit is links of rechts

b. Duim en wijsvinger in een hoek van 90 graden houden; bij de linkerhand vormt dit een "L" en bij de rechter hand niet (een omgekeerde "L")

c. Een sieraad dragen aan een bepaalde hand.

d. Nagaan aan welke kant van de weg je rijdt (in Nederland is dit rechts).

e. Ik gebruik geen strategie. Ik weet gewoon wat links is en wat rechts.

f. Iets anders, namelijk (open vraag).

4. Heb je tijdens de taak een van deze strategieën gebruikt om te bepalen welke hand van het poppetje links was en welke rechts? Zo ja, welke?

a. Nagaan wat de schrijfhand is; dit is links of rechts

b. Duim en wijsvinger in een hoek van 90 graden houden; bij de linkerhand vormt dit een "L" en bij de rechter hand niet (een omgekeerde "L")

c. Een sieraad dragen aan een bepaalde hand.

d. Nagaan aan welke kant van de weg je rijdt (in Nederland is dit rechts).

e. Ik gebruik geen strategie. Ik wist gewoon wat links was en wat rechts.

f. Iets anders, namelijk (open vraag).

5. Hoe heb je deze strategie gebruikt tijdens de test? (Als je "geen strategie" hebt ingevuld kun je deze vraag overslaan)

6. Hoe goed ben je in het bepalen van wat links en rechts is? Geef een getal tussen de 1 (zeer slecht) en de 10 (zeer goed).

7. Hoe snel ben je in het bepalen van wat links en rechts is? Geef een getal tussen 1 (zeer slecht) en de 10 (zeer goed).

8. Hoe goed ben je in het aangeven van wat links en rechts is voor iemand die tegenover je staat? Geef een getal tussen 1 (zeer slecht) en de 10 (zeer goed).

6.1.4 Non-verbal Questionnaire (on paper)

1. Heb je tijdens de taken waarbij je op het toetsenbord moest aangeven of het poppetje wel of niet een match was met de aangetikte hand in je hoofd gedacht aan de woorden “links” of “rechts?” Leg uit.

2. Heb je tijdens de taak waarbij je met de pijltjestoetsen moest aangeven of het de linker- of het rechter hand van het poppetje was, gedacht aan de woorden “links” en “rechts?” Leg uit.