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Left-right confusion: Is it caused by verbal labelling difficulty?

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Abstract

In this study, the effect of verbal labelling difficulty is explored as a possible cause of left-right confusion (LRC). It is expected that people with a high degree of LRC have trouble assigning the verbal labels of 'left' and 'right' to the referred spatial directions. Based on the Bergen left-right discrimination test, 53 participants with a low level of LRC and 24 participants with a high level of LRC were compared on a verbal labelling task. The first condition of this task required verbal labelling with the words 'left' and 'right' and the second condition required verbal labelling without these words. The hypothesis that participants with a lower degree of LRC show a larger difference between these two conditions, compared to participants with a higher degree of LRC, was not confirmed. A verbal labelling effect in LRC could not be demonstrated in this study. This suggests another cause for LRC. However, this result does not rule out verbal labelling as a cause for LRC completely, due to bias in the verbal labelling task. Further research with a larger sample size and adapted stimuli is indicated.

Keywords: Left-right confusion, verbal labelling, spatial cognition, neurocognition

1. Introduction

During childhood the ability to discriminate left from right is acquired and reaches an adult level around the age of twelve. After this age, 40% of the population experiences difficulty in this ability (Benton, 1968). A well-known cause for this phenomenon, left-right confusion (LRC) is neurological damage in the brain, for example a cerebral vascular accident (CVA) in the left hemisphere (Gold, Adair, Jacobs & Heilman, 1995). Additionally, LRC can occur without a physical cause, which is the main focus of this study.

It is not clear which cognitive or neurological processes are impaired in LRC. A few studies focused on the processes that underlie discriminating left from right and the problems that can occur. Benton (1959) described developmental problems that remain in adulthood as a possible cause of LRC. Another suggestion is that the origin lies in the asymmetry between the two hemispheres. The degree of lateralization is thought to determine one's susceptibility to LRC. People with less lateralization experience more difficulties in detecting left and right, compared to people with high lateralization of the brain (Hirnstein, Ocklenburg, Schneider, & Hausmann, 2008; Ocklenburg, Hirnstein, Ohmann & Hausmann, 2011).

This study focuses on verbal labelling as a possible cause of LRC. Verbal labelling poses a promising explanation for LRC, even though this subject has not been studied anymore after the study of Sholl and Egeth (1981). Various other explanations of LRC dominated research, partially because of the improved brain imaging, thus giving the earlier mentioned lateralization theory the upper hand. However, an actual cause of LRC has not yet been agreed upon. Verbal labelling is a promising subject to further study as a cause of LRC. Both behavioural research (Sholl & Egeth, 1981) and neurological studies (Hirnstein, Bayer, Ellison & Hausmann, 2010) indicate that verbal labelling affects participants with LRC differently than participants without LRC. These results show that verbal labelling needs to be studied more extensive.

Verbal labelling refers to assigning words to objects or phenomena, which are arbitrary (except for onomatopoeias). The verbal label itself does not reveal the meaning of this object or phenomenon. The verbal labels 'left' and 'right' to spatial directions is arbitrary, and does not explain which direction is indicated (Harley, 2010). This arbitrary labelling can create difficulty in naming spatial directions, thus causing LRC. This presupposes that LRC-patients also would experience difficulty in the verbal labelling of the spatial directions up and down. However, no problems are seen in discriminating on the vertical axis, due to asymmetry of the vertical visual world induced by gravity (Vingerhoets & Sarrechia, 2009). On the horizontal axis the environment is often symmetrical, which could create problems in discriminating left from right (Clark, 1973).

Sholl and Egeth (1981) were the first to study verbal labelling as an underlying problem in LRC. They attribute LRC to problems in the response generation stage of naming. The stimuli used are the words 'left', 'right', 'up', 'east', 'west', 'north' and 'south', which were presented vertically and horizontally. A higher reaction time was found for the words on the natural horizontal axis (east, west, left, and right) compared to a faster reaction to the words on the natural vertical axis (north, south, up, and down), independent of axis the words were presented on. This result was found and indicates the influence of verbal labels is stronger than the influence of the location of the words presented, thus revealing a verbal labelling effect. These results also underpin confusion in the horizontal axis of the spatial directions and not on the vertical axis. Furthermore, the numbers 12, 3, 6 en 9 of a clock were presented as alternative verbal labels for the spatial directions, because a clock clearly has a horizontal and a vertical axis. The reaction time did not differ significantly for the axis the numbers were presented on. This implies that the verbal labelling effect is dependent on the kind of verbal label assigned to the spatial directions (Sholl & Egeth, 1981).

Neurological evidence for the involvement of verbal labelling in LRC is found as well. LRC can originate from a lesion the left angular gyrus (ANG) in the parietal lobe (Gold et al., 1995). The left ANG is also involved in integrating spatial information with language, in this area the spatial directions are coded with verbal labels. In patients with a stroke in the left hemisphere involving the left ANG, LRC occurs. This suggests a neurological connection between verbal labelling and LRC.

Moreover, a transcranial magnetic stimulation (TMS) study found that repetitive TMS on the left ANG disrupted the ability to discriminate left from right. Impairing the right ANG with repetitive TMS yielded no effect on the ability to tell left from right. (Hirnstein, Bayer, Ellison & Hausmann, 2010). This confirms the idea that LRC originates in the left ANG and poses a problem in verbal labelling.

On the contrary, a dichotic listening (DL) study found that LRC occurs before the verbal labelling processes are active in the brain. Verbal information is processed before the language areas are active. Participants who are highly susceptible to LRC made more errors on the DL task compared to participants with a lower susceptibility to LRC. This indicates LRC originates in the brain, before verbal labelling is even activated (Hirnstein, 2011).

Because the studies mentioned above show contradictory results, this study further investigates the involvement of verbal labelling in LRC because. The degree of LRC confusability of participants is compared on discriminating left from right with verbal labelling and without verbal labelling. A task is created, which involves verbal labelling with 'left' and 'right', but also the discrimination of left and right without verbal labelling. This technique will make the influence of verbal labelling more evident. It is hypothesized that problems in verbal labelling are the cause of LRC in healthy people. A significant difference is expected in choosing a spatial direction by verbal labelling it compared to choosing a spatial direction without verbal labelling in people with a high susceptibility to LRC. In people without LRC a difference in choosing a direction with or without verbal labelling is not expected.

Besides verbal labelling three other aspects are examined, to increase knowledge of LRC: 1) the influence of gender, 2) reading ability and 3) the anchoring of spatial direction in visual perception.

First, the difference in gender between the susceptibility to LRC is studied. According to several studies using self-report to obtain the level of LRC, women seem to be more prone to LRC than men (McMonnies, 1990; Harris & Gitterman, 1978; Wolf, 1973). However, studies using a behavioural test for LRC show contrary results, with studies showing a significant correlation between gender and LRC (Bakan & Putnam, 1974; Ofte, 2002; Ofte & Hugdahl, 2002; Snyder, 1991) and studies which did not confirm this result (Hirnstein et al., 2008; Jordan, Wunstenberg, Jaspers-Feyer, Fellbrich & Peters, 2006; Ocklenburg et al., 2011). It is suggested that the difference in results from self-report and behavioural studies arise from a bias in social desirability on self-report tests. The results of self-report tests tend to reflect the stereotype of women, who are generally considered the weaker sex when it comes to spatial cognition compared to men. Thus the actual ability to discriminate left form right might not be measured (Jordan et al., 2006). To contribute to this debate, in this study scores on a self-rating LRC questionnaire as well as a behavioural LRC test are compared for men and women. A significant difference is expected on the self-report test and not on the behavioural test.

The second studied aspect of LRC is the relation between LRC, dyslexia and reading ability. A possible correlation between the degree of LRC and dyslexia may exist (Kaufman, 1980; Willows, Kruk & Corcos, 1993). This relation is attributed to the lateralization in the brain. A less lateralized brain creates problems in discrimination mirror images, compared to a stronger lateralized brain. This results in the confusion of the left and right side of the visual world inducing LRC. This also induces confusion of letters, words or sentences. This implies people who show a high susceptibility to LRC, also show a higher level of dyslexia and reading ability.

The third sub-question explores why LRC only consists on the horizontal spatial directions, and not on the vertical spatial directions. To examine this difference, the strength of the bodily feeling of the horizontal axis and the vertical axis is studied. A spatial Stroop-task should reveal if the directions of left and right are less strong presented in the body compared to up and down. This task will elaborate on the finding that humans have more trouble discriminating on the horizontal axis compared to the vertical axis (Vingerhoets & Sarrechia, 2009). It is expected the vertical axis is anchored in visual perception more strongly compared to the horizontal axis, thus a larger Stroop-effect will be revealed for the vertical axis.

2. Methods

2.1. Participants

In total 80 participants (male: 28; female: 52) were tested, with an age ranging from 19 to 35 years old (M = 23.71, SD = 2.99). Participants with an age above 35 years were excluded because spatial cognition declines after 35 years of age (Taillade et al., 2012). All participants had normal or corrected to normal vision and had no history of neurological lesions.

Participants were recruited using various methods. Flyers were handed out at psychology classes at the University of Utrecht, other neuropsychology master students of the UU will be asked to participate and friends and family will be approached.

2.2. Tasks and stimuli

The tasks were completed on a computer, with the participants' head at a distance of 34 cm from the screen. All computer tasks were developed and presented in OpenSesame. A microphone attached to the computer was used for recording reaction time in the tasks, which required verbal answering. The participants' mouth was at 10 cm of the microphone. An observer was present in the room during all the tasks and questionnaires to answer questions and note the correct answers of each participant on a premade form. All tasks and questionnaires completed by the participants are part of a larger test battery.

2.3. Bergen left-right discrimination test

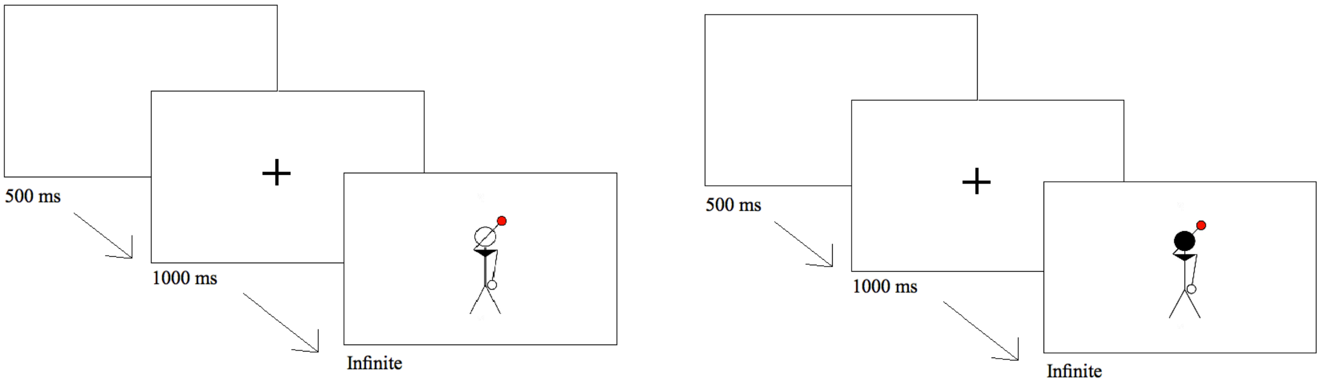
To obtain the level of LRC of the participants, a modified version of the Bergen left-right discrimination test was adopted for this study (Ofte, 2002). The test consisted of stimuli of human stick figures, presented with varying positions of the arms. The hand that was coloured red had to be verbally labelled 'left' or 'right' by the participants as fast as possible.

The trials consisted of a blank screen, shown for 500 ms, followed by a fixation cross, shown for 1000 ms, and the stimulus. The stimulus was presented until the participant verbally answered. After the answer a new trial started. See figure 1 for the trial sequence.

The participants started with a practice trial of 20 stick figures, 10 of which were presented with the front of the stick figure facing forward and the other 10 presented with the back facing forward. The actual experiment consisted of 60 presentations of stick figures in 30 different positions. Each position was presented two times, one time with the front of the stick figure facing forward (figure 1A) and one time with the back facing forward (figure 1B). The practice trials and the experimental trials were pseudo-randomized. A random order was created in Microsoft excel and this order was presented to each participant.

Based on the RT and the accuracy on these trials, the participants were classified on susceptibility to LRC. A low RT and a high accuracy implied a low susceptibility of LRC and a high RT and a low accuracy implied a high susceptibility to LRC.

The participants were instructed to keep their hands flat and still on the table, 23 cm apart and were asked to answer as fast as possible in the microphone.



A. B.

Figure 1: Trial sequence of the Bergen left-right discrimination test. A: Frontal view of the stick-figure stimulus. B: Back view of the stick-figure stimulus.

2.4. Verbal labelling-task

The verbal labelling-task was created to reveal the difference of verbal labelling of spatial directions with and without the words ‘left’ and ‘right’. The verbal labelling condition, a condition which required verbal labelling with the words ‘left’ and ‘right’, was compared to the non-verbal labelling condition, a condition in which verbal labelling with other words was required.

In both conditions a picture of a birds-eye-view of a bicycle was used as stimulus, because a bicycle has an obvious midline with a left and right side. In addition, a bicycle is a very common mean of transportation in the Netherlands. Therefore, everybody knows what it looks like.

In the verbal labelling condition the handlebar of the bicycle was coloured red on either the left or the right side. The participants were asked to answer verbally in the microphone which side of the handlebar was coloured red. See figure 2A for an example of the stimulus.

The stimulus in the non-verbal labelling condition consisted of a picture of the same bicycle, presented on a road. The road was created by two vertical white lines and a striped white line in the middle. The area inside the two outer lines is coloured light-grey and the area outside the lines is white, to optimize the perception of a road. The bicycle was presented on the left or on the right of the dotted line. See figure 2B for an example of the stimulus. In this condition, the participants were asked to verbally label the side on which the bicycle was presented. Because all traffic in the Netherlands fares on the right, participants were asked to say “correct” (“goed” in Dutch) when the bicycle was presented on the right side of the road and “incorrect” (“fout” in Dutch) when the bicycle was presented on the left side of the road. Comparing this condition to the verbal labelling condition made the effect of verbal labelling with the words ‘left’ and ‘right’ visible.

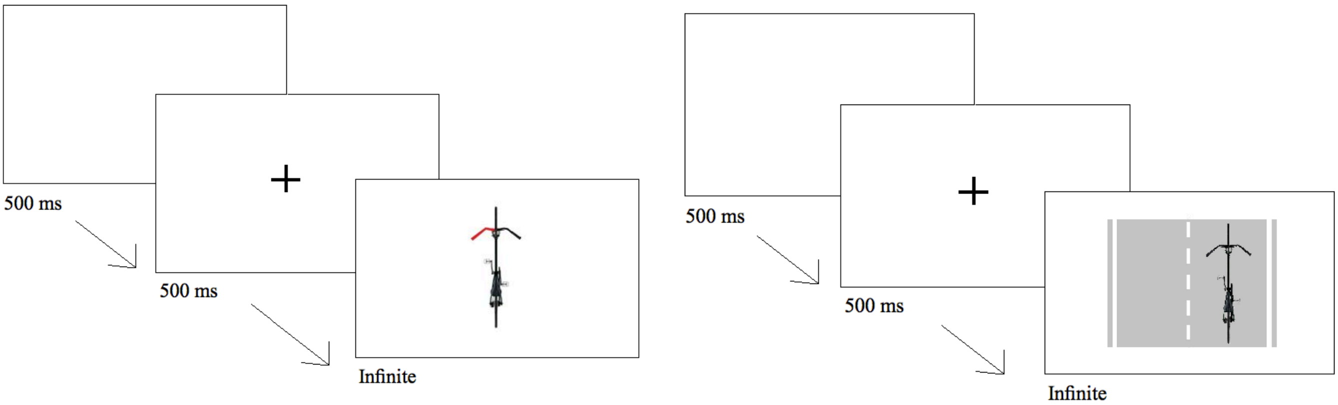
The trials of both conditions consisted of a blank screen shown for 500 ms, followed by a fixation cross shown for 500 ms, and the stimulus. The stimulus was presented until the participant answered verbally. After that, a new trial started. See figures 2 for the trial sequence.

To prevent a ceiling effect from arising on this task, the angle of the presentation of the stimuli in both conditions was varied. The conditions varied from 0°, 45°, 90°, 145°, 180°, 225°, 270° and 315°. The 0°-condition was when the front of the bicycle pointed up, the 90°-condition had the front of the bicycle pointing to the right, and so on.

The verbal labelling condition and the non-verbal labelling condition both started with eight practice trials. These eight practice trials consisted of four stimuli presented with the right side of the handlebar coloured red, placed on the right side of the road and varied in angles of 0°, 45°, 90° and 145° and four bicycles with the left side of the handlebar coloured, shown on the left side of the road and varied in angles of 180°, 225°, 270° and 315°. This way, the participants viewed both sides of the handlebar coloured, both sides of the road and all the different angles, before the actual experiment started.

The actual experiment of both conditions consisted of 32 trials, presented in a pseudo-randomized order. A random order was created in excel and every participant viewed this order. The order of the verbal labelling condition and the non-verbal labelling condition were counterbalanced, switching the order after each participant, so that each order was presented to the participants the same number of times.

The participants were instructed to answer in the microphone as fast as possible on each trial.



A. B.

Figure 2. Trial sequence of the bicycle task of the verbal-condition. A: 0° stimulus of the verbal-condition. B: 0° stimulus of the non-verbal-condition.

2.5. General questionnaire

The general questionnaire collected personal information of the participants. It was presented on paper at two separate moments during the testing. The questions that may reveal the purpose of the study and thus can create bias, were filled in after all the tasks were completed. Female participants were presented with two additional questions about their menstrual cycle. All questions are asked in Dutch because all participants are fluent in the Dutch language. The questions are included in appendix 1A.

2.6. LRC self-rating questionnaire

The aim of this questionnaire is to determine the experienced left-right confusion of the participants in real life using self-report, based on the questionnaire of Jordan et al. (2006). Like the study of Hannay, Ciaccia, Kerr and Barrett (1990), only the first four questions were relevant, and these were translated into Dutch. The questions and fixed answer options are included in appendix 1B.

2.7. Reading ability tests

Diagnosing dyslexia costs too much time to include it in this study, so instead two Dutch tests for reading ability were performed by the participants. Reading ability as a measurement was chosen because verbal fluency is seen as a component of dyslexia (Bell, McCallum & Cox, 2003). Also, Willows, Kruk and Corcos, (1993) suggest a correlation between reading ability and LRC.

The tests consist of two lists of 116 Dutch words, slowly increasing in difficulty. The first list, the One-minute-test ("Een-minuut-test" in Dutch), consists of existing words (Brus & Voeten, 1979) and the second list, the Klepel, consists of pseudowords (Van den Bos, Iutje Spelberg, Scheepstra & De Vries (1994).

The participants were instructed to correctly read as many words as possible aloud within a set time. The original maximum times were reduced to prevent ceiling effects, because the tests are originally used to obtain the reading ability in preschool children and children in the first year of high school. To set the appropriate maximum time a small pre-assessment was performed, which consisted of 6 adults who performed the One-minute-test. None of the participants finished reading the list in 45 seconds. Based on this result, the maximum time for the One-minute-test to 45 seconds (originally 60 seconds) and maximum time for the Klepel is set at 90 seconds (double of the maximum time of the One-minute-test, originally 120 seconds).

The One-minute-test was presented first, followed by the Klepel. The score of the One-minute-test and the Klepel were obtained by the number of words the participant read within the time limit minus the number of mistakes that the participant made. One point was subtracted for each word that is read incorrectly, maximum one mistake per word. A low score on the tests is a low level of reading ability and a high score is a high level of reading ability.

2.8. Spatial Stroop-task

The spatial Stroop-task was used to measure how strong the vertical and horizontal axes are represented in visual perception. In order to do this, the words 'left', 'right', 'up' and 'down' were presented on different positions on the computer screen and compared for RT.

The stimuli consisted of the words 'left', 'right', 'up' or 'down' presented in black letters on a white background on the computer screen. In the congruent condition, the presented word was congruent with the presented location. For example: 'left' presented on the left side on the screen (see figure 3). In the incongruent condition, the presented word was incongruent with the presented location. For example: 'left' presented on the right side of the screen. A neutral condition was assed to serve as a baseline RT task, in which all four words were presented in the centre of the screen. These conditions made a comparison of the Stroop-effect for the horizontal axis and the vertical axis possible. A higher Stroop-effect implies a stronger anchoring of an axis in visual awareness, and a lower Stroop-effect implies a weaker anchoring of an axis.

Each trial consisted of a blank screen shown for 500ms, followed by a fixation cross, shown for 500ms, and the stimulus. The stimulus was presented until the participant answered verbally. A new trial started when the participant verbally responded. See figure 3 for the trial sequence.

The task consisted of three different blocks. It started with a block of trials presented in the neutral-condition starting with eight practice trials ('left', 'right', 'up' and 'down' were all presented two times), followed by twelve experimental trials (all four words were presented three times). The second and the third block both consisted of eight practice trials of the words 'left' and 'right' (both words were presented congruent and incongruent two times), followed by twelve experimental trials, with the words 'left' and 'right' presented twelve times (both words were presented congruent and incongruent three times). After this, twelve experimental trials with the words 'up' and 'down' were presented only (both words were presented congruent and incongruent three times). Within each block, the order of the practice and experimental trials were pseudo-randomized and this order was presented to every participant.

The three blocks contained two different instructions to prevent a learning effect form arising. For the first two blocks, the participants were instructed to read the words that were presented on the screen aloud as fast as possible into a microphone. In the third part the participants were asked to identify the location where the word was presented and ignore the meaning of the actual word that was presented.

The task always started with the first block, in which the neutral-condition was presented only. Because the instruction for the second and the third block varied, the order of these two blocks was counterbalanced to prevent a learning effect. By switching the sequence after each participant, each order was presented to the participants the same number of times.

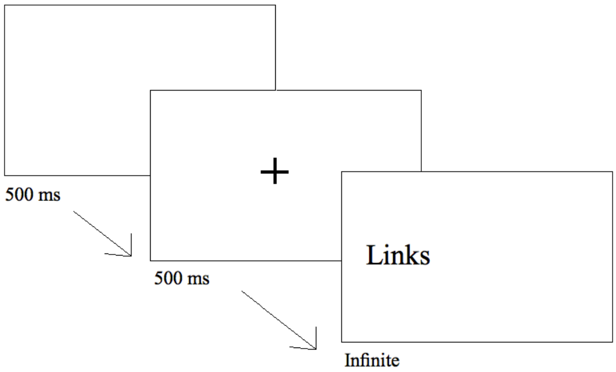


Figure 3: Trial sequence of the spatial Stroop-task of a left ("links" in Dutch) congruent trial.

2.9. *Procedure*

The total test-battery lasted approximately 45 minutes per participant. Participants were not informed about the main subject of the study in the first instruction to avoid creating bias, but only that it is about spatial cognition.

After the short introduction, participants signed the informed consent, followed by the general questionnaire, part one. After this, the computer tasks were performed. Each task was preceded by a written instruction on the computer screen, which were verbally explained by the observer as well. The Bergen left-right discrimination test and the verbal labelling bicycle task were presented in counterbalanced order. By switching the order per participant, each possible order is presented in the same quantity. After the non-verbal labelling condition the observer asked the participants what strategy they used to solve this condition. This was discussed to examine if the verbal labelling with the words 'left' and 'right' was truly eliminated.

After the Bergen left-right discrimination test and the verbal labelling task were completed, the participants performed the spatial Stroop-task, the LRC self-ration questionnaire, the One-minute-test, the Klepel and finishing with the general questionnaire part two. When all computer tasks and questionnaires were completed, optionally, a small debriefing was given explaining the goals of the different tests and the expectations of the results.

The microphone that was used was prone to errors, so special attention was directed to the use of the microphone. Participants were instructed to be as silent as possible and only speak when they were giving an answer, because if the microphone recorded a different sound

The reaction time of the actual answer is important for the research. Two errors occurred when verbally answering concerning the microphone. It could register another sound (for example the breath of the participant) during a trial and the next trial was started unfairly. Participants are instructed not to react (verbally) to this event and continue with the task when a new stimulus is presented on screen, to prevent more trials from failing. The second error is that the microphone did not register the answer of the participant, causing the stimulus to stay on the computer screen. When this event occurs the participants were instructed to repeat their answer. The participants are able to ask questions before the tests and in between conditions, when trials are not running.

2.10. Statistical analysis

To analyse the hypothesis if LRC is caused by verbal labelling a 2x2 mixed ANOVA is used. The two conditions of the verbal labelling-task were compared for the affect of level of LRC of the participants, a between-subjects variable. For comparison, two lower LRC-groups and two higher LRC-groups were defined. Both the accuracy and the RT on the Bergen left-right discrimination test were used to classify these groups. Participants who are highly susceptible to LRC will show a low accuracy and a high RT. For the participants who are less susceptible for LRC the opposite results are seen. The classification is based on these assumptions. Thus for the LRC groups classified by accuracy, all participants with a below average score form the lower LRC-group-Acc and all participants with an above average score form the higher LRC-group-Acc. For the LRC-groups classified by RT on the Bergen left-right discrimination test, all participants with an above average RT form the higher LRC-group-RT and all participants with a below average RT form the lower LRC-group-RT.

To test the hypothesis if the horizontal spatial directions are weaker represented in visual perception compared to the vertical spatial directions, a 2x2x2 repeated measures ANOVA is performed. The two spatial directions of the spatial Stroop-task (horizontal and vertical) are compared with the two congruency conditions (congruent and incongruent) and the two instruction conditions (word and location). This test will reveal if the horizontal axis differs significantly from the vertical axis. Separate analyses will be performed to analyse the difference within the word-instruction and within the location instruction. To analyse the word instruction a 2x3 repeated measures ANOVA is performed with the horizontal and vertical axes compared for the neutral, congruent and incongruent conditions. To analyse the location-instruction a 2x2 repeated measures ANOVA is performed, with the two axes compared for the congruent and incongruent conditions.

Correlation analyses are performed for the correlations between LRC and gender, LRC and handedness, LRC and reading ability and LRC and the menstrual cycle.

Outliers in the data of the participants were defined using the outlier labelling rule, with g equal to 2,2 (Hoaglin & Iglewicz, 1987) which lead to the deleting of individual RTs of the participants. After the elimination of the individual trails, outliers between participants were defined, leading to the deleting of the mean RTs of three participants of the bicycle task. Three other participants identified as an outlier on the spatial Stroop-task and were deleted.

Individual trials were also deleted when the two possible errors with the microphone occurred. During the performing of the tests, an observer was present to record failed trials, which were later individually deleted. Individual RTs under 300 ms are deleted as well, these RTs are likely to arise because of a problem with the microphone.

3. Results

3.1. LRC and speed and accuracy on the verbal labelling task

Based on the accuracy of the verbal labelling task, 53 participants were classified in the lower LRC-group (M = 97.05 %, SD = 1.79) and 24 participants in higher LRC group (M = 85.15 %, SD = 8.00). A 2x2 mixed ANOVA compared these two groups (defined with a between subjects variable) on the two conditions of the verbal labelling task (within factors variable). The results are shown in table 2. A main effect for the verbal labelling-task is revealed ($F = 95.11$, $p<0.01$). Participants showed significant higher mean RTs for the non-verbal labelling condition compared to the verbal labelling condition. The interaction of the two LRC-groups and the performance (accuracy and RT) of the verbal labelling-task did not show a significant result.

Table 1

Results of the main-effect of the verbal labelling condition and the non-verbal labelling condition.

	df	M (ms)	SD	F	η2	β	p
Verbal labelling condition	72	762.68	147.60	95.11	.720	1.00	<0.01*
Non-verbal labelling condition	72	1044.21	222.95				

*Significant

3.2. LRC and gender

The difference between men and women in LRC was analysed with a correlational analysis between gender, the Bergen left-right discrimination test (RT and accuracy) and the LRC-self rating questionnaire. The results are shown in table 3.

A trend was found for gender and the accuracy on the Bergen left-right discrimination test (r = -.06, p = .63). Men show a higher accuracy on the Bergen left-right discrimination test compared to women.

The correlation between the LRC self-rating questionnaire and gender showed a significant correlation (r = .44, p<0.01). Men obtained an average lower score (thus less LRC) on the self-rating questionnaire compared to females.

Table 2

The results of the correlations of gender, the LRC-behavioural test and the LRC self-rating questionnaire.

	Male			Female				
	df	M	sd	df	M	sd	r	p
LRC self-rating questionnaire	27	5.75	1.84	51	8.60	3.23	.44	<0.01*
Behavioural LRC-test (RT	27	1157.34	269.90	51	1302.20	352.84	.21	.06

ms)								
Behavioural LRC-test (accuracy %)	27	93.88	7.15	51	87.47	7.26	-.06	.63

**Significant*

3.3. LRC and reading ability

In table 4 the results of the correlational analyses of the Bergen left-right discrimination test and the One-minute-test and the Klepel are shown. The scores on the One-minute test are correlated with the scores of the Klepel ($r = .66$, $p<0.01$). If a participant scores higher on the One-minute-test, the score on the Klepel will also be higher. Besides this result, a significant correlation between the One-minute-test and the RT on the Bergen left-right discrimination test ($r = -.23$, $p<0.05$). A higher RT on the Bergen left-right discrimination test, is related to a lower score on the One-minute-test.

Table 3

Results of the correlational analysis of the reading ability tests and the RT of the Bergen left-right discrimination test.

	df	M	sd	r	p
One-minute-test	79	85.19	12.52	.65	<0.01*
Klepel	79	87.53	14.47		
				One-minute-test	
Bergen left-right discrimination test	79	1251.49	331.81	-.23	<0.05

*Significant

3.4. Spatial Stroop-task

A 2x2x2 mixed ANOVA is performed to view the difference between the horizontal stimuli and the vertical stimuli, as well as the word and the location conditions of the spatial Stroop-task. The results can be viewed in table 4 and 5. A significant main effect for congruency is found ($F = 227.45$, $p<0.01$), with a higher reaction time for the incongruent condition compared to the congruent condition.

The mixed ANOVA also reveals three interaction effects. First, a significant interaction is found between axis an congruency ($F = 6.71$, $p<0.05$), implying the horizontal axis is effected differently by the congruency compared to the vertical axis. The results are shown in figure 4. A larger difference in reaction time between the congruent and incongruent condition is seen in the vertical axis, compared to the reaction time between the congruent and incongruent conditions in the horizontal axis.

Second, a significant interaction between congruency and instruction is found (F = 12.17, p<0.01). The results are shown in figure 5. Participants show a larger difference in RT between the congruent and incongruent condition for the location-instruction, compared for the difference between the congruent and incongruent condition for the word instruction.

Third, a significant interaction between axis and instruction is found (F = 31.28, p<0.01). The results are shown in figure 6. Participants show larger difference between the RT of the horizontal- and the vertical-condition for the word instruction, compared for the RT of the horizontal- and the vertical condition for the location-instruction.

Table 4

RT (ms) of the horizontal, vertical, congruent en incongruent conditions of the spatial Stroop-task.

Instruction		Conditions					
		Congruent			Incongruent		
		df	M	sd	df	M	sd
Word	Horizontal	76	543.36	72.42	76	580.62	73.68
	Vertical	76	520.89	61.83	76	558.19	67.15
Location	Horizontal	76	506.01	95.78	76	546.80	103.98
	Vertical	76	512.72	101.45	76	587.15	107.60

Table 5

Results of the main effect and the interaction effects on the spatial Stroop-task.

	F	η2	β	p
Main effect congruency	227.48	.75	1.00	<0.01*
Axis * congruency	6.71	.08	.73	<0.05*
Congruency * instruction	12.17	.14	.93	<0.01*

Axis * instruction	31.28	.29	1.00	<0.01*

*Significant

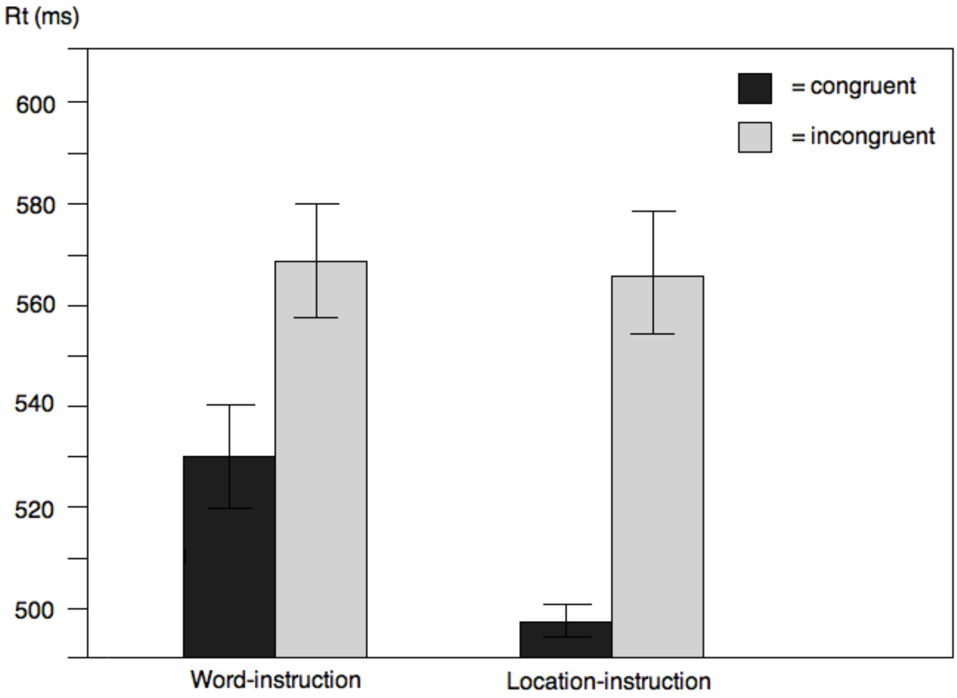


Figure 4. Bar-graph of the interaction of axis * congruency on the spatial Stroop task.

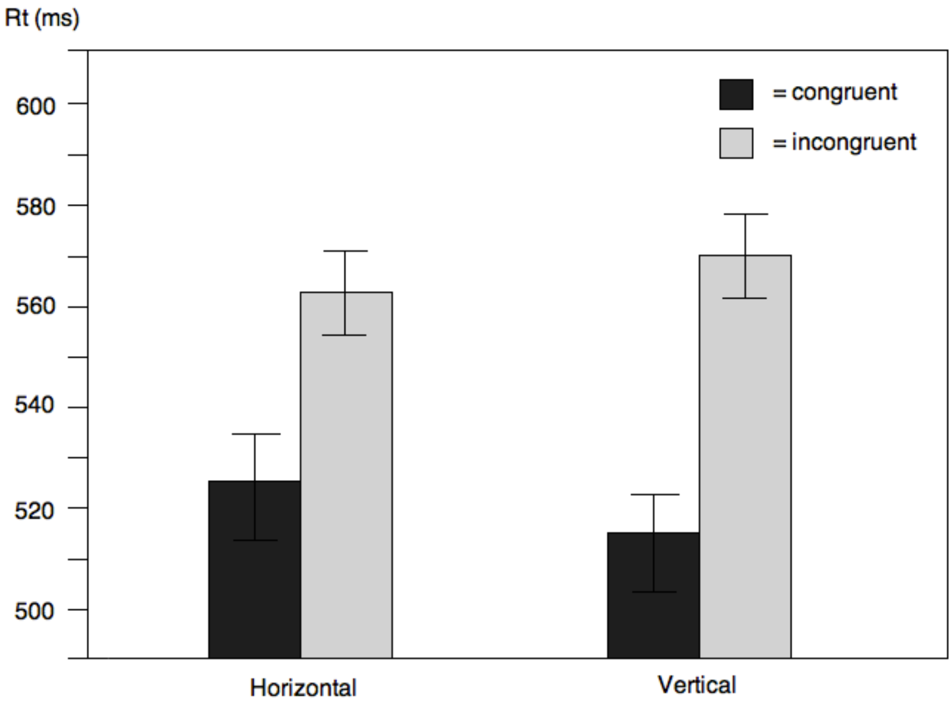


Figure 5. Bar-graph of the interaction of congruency * instruction of the spatial Stroop-task.

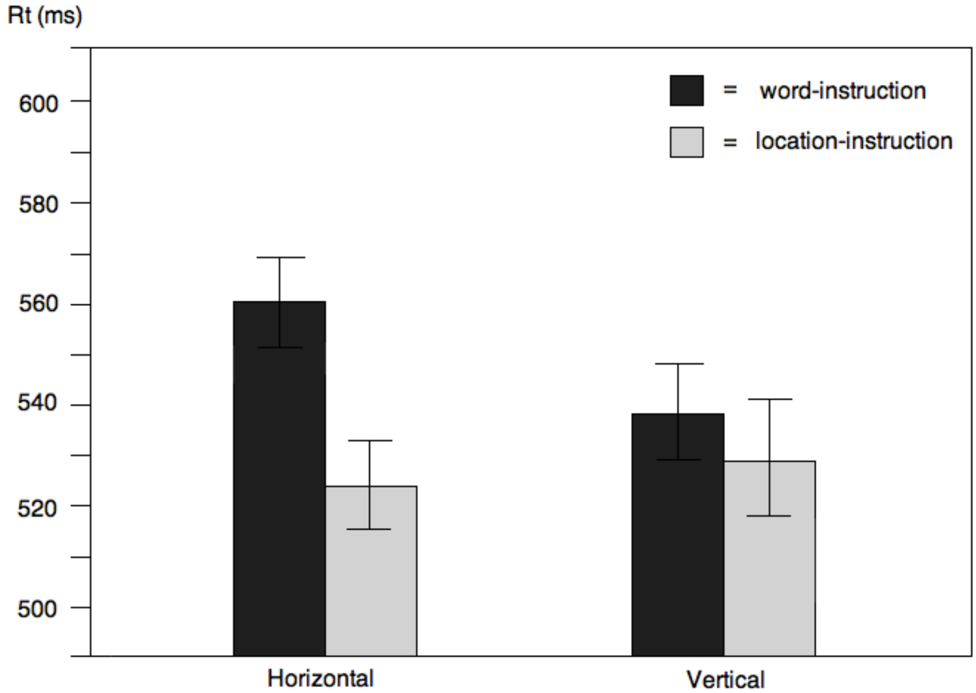


Figure 6. Bar-graph of the interaction of axis * instruction of the spatial Stroop-task.

Because these analyses show significant results, a separate 2x3 repeated measures ANOVA is performed for the word-instruction and a 2x2 repeated measures ANOVA is performed for the location instruction. These results are shown in table 6. When analysed separately for the word condition, with neutral, congruent and incongruent compared for the horizontal and vertical axis, a significant main effect of congruency ($F = 85.51$, $p<0.01$) with a higher RT on the incongruent condition compared for the congruent condition. A main effect is also found of the axis ($F = 23.87$, $p<0.01$), with a higher RT for the horizontal axis compared to the vertical axis.

The 2x2 ANOVA for the location condition shows a main effect for axis ($F = 153.02$, $p<0.01$), with a higher RT for the horizontal axis versus the vertical axis. Besides this result, a main effect for congruency is revealed as well ($F = 11.72$, $p<0.01$), showing a higher RT for the incongruent condition compared to the congruent condition. Lastly, a significant interaction effect is found between axis and congruency ($F = 10.00$, $p<0.01$). A larger difference in RT between the congruent and the incongruent condition is seen for the vertical axis compared to the difference in RT between the congruent and incongruent condition for the horizontal axis.

Table 6

Results of the main effects and interaction effect for the word- and location-instruction analysed separately.

		F	η2	β	p
Word	Main effect congruency	85.51	.54	1.00	<0.01*
	Main effect axis	23.87	.24	.99	<0.01*
Location	Main effect congruency	11.72	.13	.92	<0.01*
	Main effect axis	153.02	.69	1.00	<0.01*
	Axis * congruency	10	.12	.88	<0.01*

*Significant

4. Discussion

In this study, verbal labelling problem is examined as a possible explanation of LRC. Based on the degree of LRC, measured with a behavioural LRC test, a lower LRC-group and a higher LRC-group are classified. To verify for a verbal labelling effect, these two groups were compared on the performance on a task that required verbal labelling with the words ‘left and ‘right’ and verbal labelling without the words ‘left’ and ‘right’. A significant difference for the two LRC-groups on the two verbal labelling task conditions was expected according to the results of the study of Sholl and Egeth (1981). However, this result could not be confirmed in this study. The higher and the lower LRC-groups did not perform significantly different when verbal labelling with the words ‘left’ and ‘right’ was required, compared to the when this was not required.

These results suggest verbal labelling is not a part of LRC. This was also found in the study of Hirnstein (2011). Using a dichotic listening task where participants have to pay attention to sounds in one specific ear, it was found that participants with a higher level of LRC made more mistakes compared to the participants with a lower level of LRC. The processing of auditory information takes place at an earlier stage compared to verbal labelling. This suggests that the problem of LRC arises in the brain before the process of verbal labelling is active. Thus ruling out verbal labelling as a possible cause in LRC. In addition, the study of Gold et al. (1995) described a patient who suffered from the Gerstmann syndrome, with LRC as a symptom, but he did not show any problems in verbal labelling. These results imply that verbal labelling does not have an effect on the degree of LRC.

Three additional secondary questions about LRC were examined in this study. First, the difference between men and women on performance on LRC tests was analysed. This study did not show a significant difference between men and women compared to performance on behavioural tests of LRC, but this effect was found for the LRC self-rating questionnaire. The LRC self-rating questionnaire demonstrated a lower level of LRC for men compared to women. The behavioural test did show a trend in the correlation with gender, suggesting further research is needed with a larger sample size.

These results are partially in accordance with earlier performed studies. A significant difference between the performance of men and women on LRC-tasks was reported, with men showing a lower level of LRC compared to women (Wolf, 1973). However, due to self-report measurements this result can be attributed to a social desirability bias. Women are stereotyped to perform lower than men on LRC. Using behavioural tests to obtain the level of LRC, the results remain contradictory. Several studies report a significant better performance by men compared to women (Bakan & Putnam, 1974; Ofte, 2002; Ofte & Hugdahl, 2002) and several studies did not report a significant difference (Jordan et al., 2006; Hirnstein et al., 2008; Ocklenburg et al., 2011). A consensus on these results has not been reached. The sample size of this study is too small to reveal a significant result, but it may be revealed in a larger sample size. Further study testing more participants will show if men and women actually perform differently on LRC using behavioural tests. This study does confirm that the measuring LRC by using self-report is not a viable method and mostly measures the current stereotype of men and women.

Second, a relation between dyslexia and LRC, as well as reading ability and LRC were suggested (Gold et al., 1995, Willows, Kruk & Corcos, 1993). To test the correlation between reading ability and LRC, the participants performed a reading ability test. The results do not confirm a significant correlation between reading ability and LRC. In addition, a significant correlation between dyslexia and LRC was not found. This result is possibly due to the extreme low number of dyslexic participants (only two participants reported to be officially diagnosed with dyslexia), so further research testing a larger sample of dyslexic participants is needed.

These same results were found in several studies (Willows, Kruk & Corcos, 1993; Corballis, Macadie, Crotty & Beale, 1985). On the contrary, two reviews show an overall supporting result of the correlation. They argue that a proper sense of left and right is needed to read letters, words and sentences correctly. When a high level of LRC occurs, the words, letters and sentences are confused more easily, possibly inducing problems in reading ability or dyslexia (Kaufman, 1980; Willows, Kruk & Corcos, 1993).

The third sub-question concerns the confusion of the words 'left' and 'right' compared to and the words 'up' and 'down'. The horizontal spatial directions are confused, but the vertical spatial directions are not (Vingerhoets & Sarrechia, 2009). Does this imply the horizontal axis is anchored weaker into our visual perception compared to the vertical axis? A spatial Stroop-test was created to test this hypothesis. This test showed a significant larger Stroop-effect for the vertical axis compared to the horizontal axis. This implies the horizontal axis is indeed anchored weaker in our perception compared to the vertical axis, adding another explanation why the spatial directions left and right are more confused compared to up and down. Moreover, the vertical axis of our natural world has a clear distinction between up and down, induced by gravity. The horizontal axis shows more symmetry and is therefore more easily confused (Vingerhoets & Sarrechia, 2009). In future research, brain imaging techniques can be used to examine if discriminating on the vertical axis or on the horizontal axis activate different areas and processes in the brain.

In conclusion, the results of the verbal labelling task could not demonstrate a verbal labelling effect in LRC. It should be noted that verbal labelling with the words 'left' and 'right' might not have been eliminated completely from the verbal labelling task. Several participants used the words 'left' and 'right' in the non-verbal labelling condition. These participants first decided if the bicycle was presented on the right side or the left side of the road, and then decided if that was the correct side of the wrong side to be driving on the road. This process possibly caused the words 'left' and 'right' to be activated in the brain, which implies verbal labelling with these words might not be completely eliminated out of this condition. Therefore, the comparison of the verbal labelling condition and the non-verbal labelling condition possibly shows a main effect of the task, rather than a verbal labelling-effect. This implies further research is needed with an adapted stimulus, to fully eliminate the left-right verbal labelling, which makes accurate verbal labelling-effect visible.

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Appendix 1: Questionnaires and reading ability tests

A: General questionnaire

Part 1:

1. Geslacht (man/vrouw)
2. Leeftijd:
3. Wat is uw hoogst afgeronde opleidingsniveau? Bent u op dit moment bezig met een opleiding?

Part 2:

1. Heeft u dyslexie? (ja/nee)
2. Heeft u dyscalculia? (ja/nee)
3. Kunt u fietsen? (ja/nee)
4. Op welke leeftijd heeft u leren fietsen?
5. Hoe vaak fietst u gemiddeld per week?
6. Heeft iemand in uw familie last van links-rechts verwarring? (ja/nee) Zo ja, wie?
7. Hoe heeft u het onderzoek ervaren?
8. Had u een specifieke strategie voor het oplossen van de ruimtelijke computer taken (De poppetjes taak en de taken met de fiets)? (ja/nee)
   Zo ja, wat voor strategie?
   Vraag 9 en 10 dienen alleen ingevuld te worden door vrouwen.
9. In welke week van uw menstruele cyclus bent u nu?
10. Gebruikt u hormonale anticonceptie? (ja/nee)
    Zo ja, wat voor soort anticonceptie?

B: LRC self-rating questionnaire

1. Weet u het verschil tussen links?
2. Als volwassene heb ik moeilijkheden bij mezelf geconstateerd wanneer ik snel links of rechts moet benoemen
3. Wanneer iemand me vertelt links of rechts af te slaan als ik aan het rijden ben in een *bekend* gebied, heb ik moeilijkheden met snel beslissen welke kant ik op moet gaan

4. Wanneer iemand me vertelt links of rechts af te slaan als ik aan het rijden ben in een *onbekend* gebied, heb ik moeilijkheden met snel beslissen welke kant ik op moet gaan.

Answer options:

1 = Nooit

2 = Bijna nooit

3 = Soms

4 = Regelmatig

5 = Altijd