Change Blindness for State Changes when using an Extended Identity Cue

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Abstract

People sometimes are unable to detect visual changes in their environment, a phenomenon known as change blindness. This study focused on change blindness for objects changing in state. It also looked at people's confidence about their performance and whether the cue influenced performance. Because of object-location binding theory, it was expected that distance and location influence change blindness. People were expected to detect the change best when the changed object shared identity with an adjacent, rather than non-adjacent, object. People's confidence was expected to be similar to the expected performance. Because of interference processes, it was expected that people would perform better and be more confident with an extended (present during post-change display) instead of a non-extended (disappeared before post-change display) identity cue. The 34 participants had to detect which object had changed between the pre-change and post-change display. Afterwards, they rated their confidence with their answer. Results were analyzed with a repeated measures ANOVA, a paired t-test and an independent samples t-test. For response accuracy, distance had influence in both conditions of target identity, whereas it was expected distance would only have influence in the shared condition. For confidence, the expected interaction was found. Furthermore, people scored better with an extended than a non-extended identity cue. However, the confidence level did not differ for the different types of identity cues.

Keywords: Change blindness, visual working memory, interference, state changes, neural binding processes, confidence

Change Blindness for State Changes when using an Extended Identity Cue

Do you remember playing this game as a child? You had to look at objects on a table for a moment, before turning your back at the table. Then someone put one of the objects at a different spot. When you turned around you had to guess which object was moved. Sometimes you easily noticed it, other times it was hard. The times that you could not notice the changed object, change blindness came along. When people are unable to detect changes in their environment, although they must have been able to notice, this is referred to as change blindness (Simons & Levin, 1997). This does not only happen with the objects on the table in a child's game but occurs in many different everyday situations. Research has been done on different aspects of change blindness, but there are still questions arising on what mechanisms are behind it. Why does it occur in one situation but not in others? This research will follow up on a few previous studies on change blindness to get a closer look into change blindness for state changes.

Previous studies

Braam (2021), Drake (2021), Dzhurkov (2021), Koot (2021) and Ważny (2021) looked at the role of object location and identity in change blindness. They looked at two kinds of object changes: state changes and exemplar changes. A state change is a change in the state of an object, like open – closed or full – empty. An exemplar change is when an object is changed for another example of that object, like replacing one guitar for a different guitar. They used two kinds of cues: location cues (Drake, 2021; Dzhurkov, 2021; Koot, 2021; Ważny, 2021) and identity cues (Braam, 2021). A location cue is a line pointing from the center to one of the objects in the display. An identity cue is a picture of one of the objects in the display, which is adjacent to the changed object (*target*). The identity cue cannot be the target, because in that case people would compare the target to the cue instead of the memory they have of the pre-change display. For the location cue, the target was always adjacent to the cue too, to make sure comparisons between experiments could be made to look at the influence of the cue on change blindness.

Results of the previous studies (Braam, 2021; Drake, 2021; Dzhurkov, 2021; Koot, 2021, & Ważny, 2021) showed that people were better at detecting the change when the target shared identity with another object in the display, than when it did not share identity. For the studies on exemplar changes, results showed that location played a role too (Drake, 2021; Dzhurkov, 2021). People were better at detecting changes when the identical objects were adjacent, than when there was another object in between. An interaction between identity and location was also found for the exemplar changes (Drake, 2021; Dzhurkov,

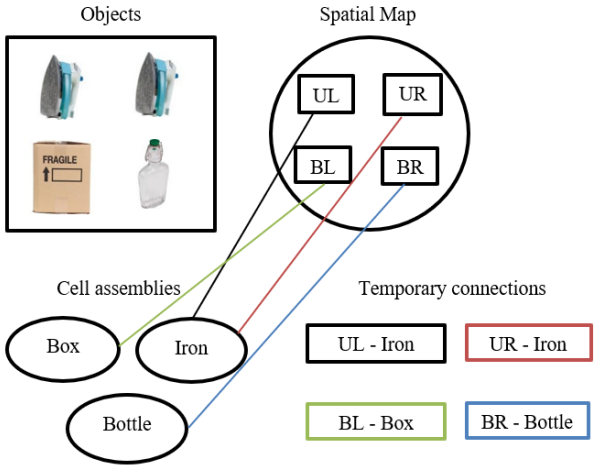
2021). Participants were best at detecting changes when the target shared identity with another object and that object was adjacent. This interaction effect was not found for state changes (Braam, 2021; Koot, 2021; Ważny, 2021).

The influence of a second object, identical to the target, on change blindness was expected because of binding processes (De Vries, 2004). When we look at an object, we make a temporary mental connection between the location and identity of the object. On the structural level a location from the spatial map becomes bound with a cell assembly that represents the identity of the object (Figure 1). This temporary connection gets fully activated when the excitation level of the cell assembly is high enough to reach the *critical threshold*. On the functional level, this means that when the critical threshold for a cell assembly is reached, the temporary location-identity association of an object is in our visual working memory.

When there are two identical objects, the cell assembly representing that identity gets activated twice because it is bound with two locations from the spatial map. This can be seen in Figure 1, where the cell assembly for 'iron' is activated by both presented images of the same iron. Because of this extra activation, the critical threshold for the cell assembly 'iron' is more likely to be reached, increasing the chance that the location-identity association of both irons will be present in visual working memory. This means that people will be better at remembering an object and its location when that same object is also presented at another location, as was found in the previous studies (Braam, 2021; Drake, 2021; Dzhurkov, 2021; Koot, 2021, & Ważny, 2021).

Figure 1

The binding process



Note. Location in the spatial map: upper left (UL), upper right (UR), bottom left (BL), bottom right (BR).

The binding process happens serial according to the model proposed by De Vries (2004). It was therefore expected that the location of the identical object would have influence on the performance on change blindness tasks (Braam, 2021; Drake, 2021; Dzhurkov, 2021; Koot, 2021; Ważny, 2021). When different objects are presented, the temporary connection for one object is made after the binding of another object (De Vries, 2004). This way, wrong locations are less likely to become bound with wrong identities. When two similar objects are next to each other, they will be bound directly after each other. In Figure 1, the second iron would be bound right after the binding of the first iron is finished. The cell assembly 'iron' is then still active when it is activated again for the binding of the second iron. This makes it more likely that the critical threshold for that cell assembly is reached by the extra activation of the second iron than when there would be a different object in between the binding of the two irons. Because in that case, the cell assembly would be less activated, or not activated anymore by the first iron when the binding is done for the second iron. This second activation of the cell assembly might then not be enough for the excitation level to reach the critical threshold. So, the object-location association is more likely to be in visual working memory when identical objects are adjacent instead of non-adjacent. However, in the previous studies this effect was only found for exemplar changes (Drake, 2021; Dzhurkov, 2021) not for state changes (Braam, 2021; Koot, 2021; Ważny, 2021).

This gave rise to the question why the state changes did not show the distance effect (Braam, 2021; Koot, 2021; Ważny, 2021). Therefore, the current study will take a closer look at state changes. It will look at the role of distance and identity in change blindness for objects changing in state. The experiment of the previous study of Braam (2021) will be modified and extended by looking at the role of the cue and confidence of participants in the recall of changes. This study is part of a larger study on this topic.

Difficulty

One explanation for the occurrence of the distance effect for exemplar changes (Drake, 2021; Dzhurkov, 2021) but not for state changes (Braam, 2021; Koot, 2021; Ważny, 2021) might have to do with difficulty. State changes are more subtle than exemplar changes, which might be a reason that participants said they found it hard to detect changes in the experiment of Braam (2021) on state changes using an identity cue. A box that is open or closed (state change) might be harder to see a change in than a box that is replaced with a different box (exemplar change). The two boxes in an exemplar change are two different

objects and therefore differ on more aspects than a state change, which might make it easier to detect changes.

Because of this difficulty, the current study will make changes to the identity cue experiment of Braam (2021) to simplify the experiment. There will always be an object that changes. So, the 'no change' option is omitted. Besides, the identity cue will still be present during the post-change display, instead of only between the pre-change and the post-change display like a non-extended identity cue. It will therefore be called an extended identity cue. With these adjustments, it is expected that the experiment will be easier than the experiment of Braam (2021). And as a simpler task, like the exemplar changes, did show an interaction effect for distance and identity, it is expected that the simplification of the experiment of Braam (2021) will lead to the occurrence of a similar interaction effect.

The interaction effect is also expected because of binding processes (De Vries, 2004). It is expected that distance does have influence when the target identity is shared, but not when target identity is not shared (Hypothesis 1). It is expected that people score best on adjacent, identical objects. Just as was found for the exemplar changes (Drake, 2021; Dzhurkov, 2021). An effect for distance is not expected in the non-shared condition, because the target is not one of the identical objects. If people have a better memory of the identical objects when they are adjacent, it does not increase the memory of the target when that is not one of the identical objects. Also, it is expected that people are better at detecting state changes when the target shares identity with another object, than when the target does not share identity (Hypothesis 2), because the double activation of the cell assembly increases the chance of the excitation level to reach the critical threshold (De Vries, 2004).

The third hypothesis follows from these hypotheses. It is expected that distance does have influence on how confident people are with their answer when the target shares identity but not when target identity is non-shared (Hypothesis 3). It is expected that people will be most confident about detecting the right change when the target shares identity with an adjacent object. That is the situation in which the critical threshold for the cell assembly is most easily reached. Which means that in that situation the chance that the target is present in visual working memory is the highest. Therefore, the change will be more easily noticeable, making people more confident about their answer. It is interesting to look at confidence ratings, to see people's own perception of their ability to detect changes. Especially since the 'no change' option is omitted in the current study, leaving only two choice options.

Interference

Visual working memory capacity is limited (Hartshorne, 2008). According to the continuous resource theory, the more items must be remembered, the worse the memory of all the items will be (Luck & Vogel, 2013). This might have played a role in the experiment of Braam (2021) because the identity cue was not present during the post-change display. Therefore, people had to remember the cue while also having to remember the objects in the pre-change display. This will make the memory of the items in the pre-change display slightly less detailed (Luck & Vogel, 2013). This loss of detail makes it harder to detect changes.

Besides, it might also function as a secondary task when participants must remember the identity cue. Performing a secondary task while doing another task, might interfere with the primary memory task (Marshev, Chetverikov & Kuvaldina, 2016). In the task of Braam (2021), participants had to remember the identity cue. This might have interfered with the memory of the pre-change display, which was the primary task. This might have decreased the visual working memory capacity for the objects in the pre-change display (Hartshorne, 2008). Both the secondary task interference and the continuous resource theory explain why the non-extended identity cue might make it harder to remember the objects in the pre-change display, making it harder to detect changes.

Interference might have more influence on the detection of state changes than the detection of exemplar changes. As already mentioned, state changes are subtle changes and identity changes are more obvious. When your memory of an object is less detailed, it will probably be hard to remember whether a box was already closed or not. It might be easier to remember whether that box already was red and round. To notice a state change, you need a more detailed memory then for noticing an exemplar change. This could be a reason that the studies on state changes showed different results than those on exemplar changes (Braam, 2021; Drake, 2021; Dzhurkov, 2021; Koot, 2021; Ważny, 2021).

To see if it has impact on state change detection when participants have to remember the cue, the identity cue will be extended in the current study. The cue will still be present during the post-change display. This way, the interference of having to remember the cue is not present. It is therefore expected that performance on change blindness tasks in the current study with the extended identity cue will be better than performance on tasks with a non-extended identity cue like the one of Braam (2021) (Hypothesis 4). It is also expected that people will be more confident that they detected the state change with an extended identity cue, than with a non-extended identity cue (Hypothesis 5), because they will have a more

detailed memory to compare the post-change display to when there is an extended identity cue.

Method

Participants

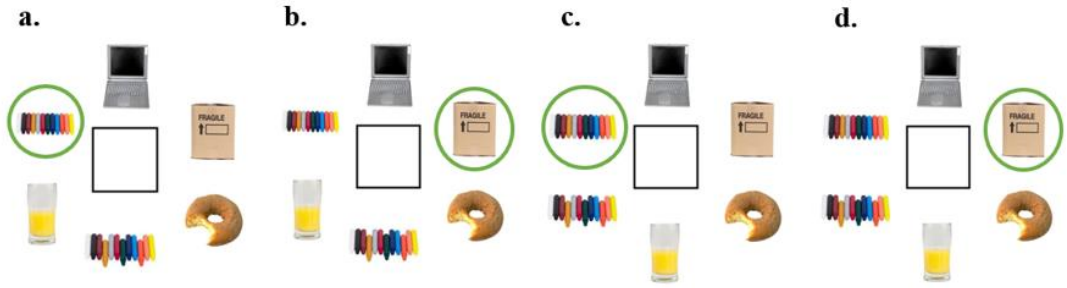
Fifty-three people participated in the experiment. Twelve participants did not complete the study and were excluded from the analysis. Seven people did not answer according to the assignment by repeatedly pressing the cue or an object non-adjacent to the cue. These people were also excluded from the analysis. Of the 34 participants included in the analysis 26 were gathered via a participant pool of first year Psychology students at the University of Groningen, called SONA (6 male, 20 female, M_{age} = 20.58, SD = 3.01). The other participants were volunteers gathered via the social circle of the researcher (1 male, 7 female, M_{age} = 23.75, SD = 10.70). Participants in the SONA pool got credits for their participation, which they need to collect to pass a first year Psychology course. The volunteers did not receive a reward for their participation.

Design

The study was a 2x2 repeated measures design. The participants in the study participated in all conditions. The selection of the images for a trial was done randomly, based on their categories. All images had an equal chance to appear in each location and function (target, cue, identical object) in the trials. The different trials were randomly distributed over the participants to exclude any order effects. Each participant got 28 trials for each condition. One independent variable was the identity of the target (shared/non-shared). When the target identity was shared, the target was one of the two identical objects. In the non-shared condition, the target was not one of the two identical objects. The other independent variable was the distance between the two identical objects (adjacent/non-adjacent). When the two objects were non-adjacent, there was always one object in between the two identical objects. In each trial two objects were identical. The dependent variables were the response accuracy (hit/miss) and the confidence rating (a five-point scale reaching from absolutely not confident, to absolutely confident). The different conditions are presented in figure 2.

Figure 2

The different experimental conditions



Note. The green circle indicates the target of the experiment. **a.** shared, non-adjacent. **b.** non-shared, non-adjacent. **c.** shared, adjacent. **d.** non-shared, adjacent.

Material and stimuli

Via http://konklab.fas.harvard.edu/ (Brady, Konkle, Oliva, & Alvarez, 2012), a total of 48 images of state changes were selected for the study. We selected objects that participants would be familiar with, like boxes, bottles and food. We also selected objects that could be grouped into categories. The selected images were divided into six different categories, each consisting of four pairs of images (Appendix A). A pair of images consisted of two pictures of the same object but in two different states (Figure 3). This way the only change in a pair is a change in the state of the object. Therefore, the results of the study will inform us about the occurrence of change blindness for state changes, and potential third variables about the kind of change are excluded. The different categories were storage, household appliances, electronics, entertainment, drinks, and baking. It was made sure that the images in one category did not fit into one of the other categories of the experiment. This was done to exclude a possible effect for similarity of objects in the display. It might be easier to remember objects that share some features or goals, like a pumpkin pie, a cheesecake and a donut. These are all sweet foods, so when these objects would be present at the same time, participants could link them to the same category. This might make it easier to remember these images. The grouping of the images might interfere with the identity variable measures of the experiment. By dividing the images into mutually exclusive categories before the experiment and only presenting one item out of a category in a trial, this effect would not occur. Therefore, the only similar items in the display are the two identical items which are used for the shared identity measures.

Figure 3

Example of an object pair reflecting a state change

Procedure

The experiment was carried out online. Participants had to complete it at a self-chosen, quiet location on their own laptop or computer. The first part of the study took place via Qualtrics (Qualtrics, 2005). Participants read what was expected of them and which data would be collected. Afterwards, the participants signed the informed consent, in which was mentioned that participation was fully voluntarily and that participants could stop at any moment without consequences. It also stated that data was collected anonymously. The Ethical Committee of the Faculty of Behavioral and Social Sciences at the University of Groningen has approved the study and informed consent. After participants agreed to the informed consent, they read the instructions of the experiment. Afterwards, they were redirected to OSWeb (Mathôt, & March, in press), the online environment in which the experiment was carried out. Participants first completed two blocks of 8 practice trials. Afterwards, the participants completed 4 blocks of 24 trials. At the end of each block their score, consisting of the proportion of correct answers in that block, was presented. At the end of the experiment the participants got a short explanation of the hypotheses and a graphical depiction of their overall performance compared to the hypotheses.

An example of a trial is shown in Figure 4. The duration of the screens is presented in Table 1. Each trial started with a blue square in the center that participants had to click. After that, each trial in the experiment consisted of four screens: the pre-change display (screen 1), the mask with the cue (screen 2), the post-change display (screen 3), and the confidence rating (screen 4). The pre-change display showed six images of five different categories. The images were presented as images of 2.5 cm x 2.5 cm. Two of the images in the pre-change display were from the same pair. These could either be in a similar or a different state. The identity cue was presented during the mask and the post-change display. The cue always was one of the images in the pre-change display. One of the objects adjacent to the cue had

changed in the post-change display, which means that one of the images adjacent to the cue was replaced with the other image of the pair. During the post-change display, participants had to click on the object they thought had changed. After their response, they had to rate how confident they were with their answer on a five-point scale. During the practice trials the participants received feedback after each trial. The square in the center of the screen turned green for a correct response and red for an incorrect response. This feedback was not given during the non-practice trials.

Figure 4

The different screens of a trial

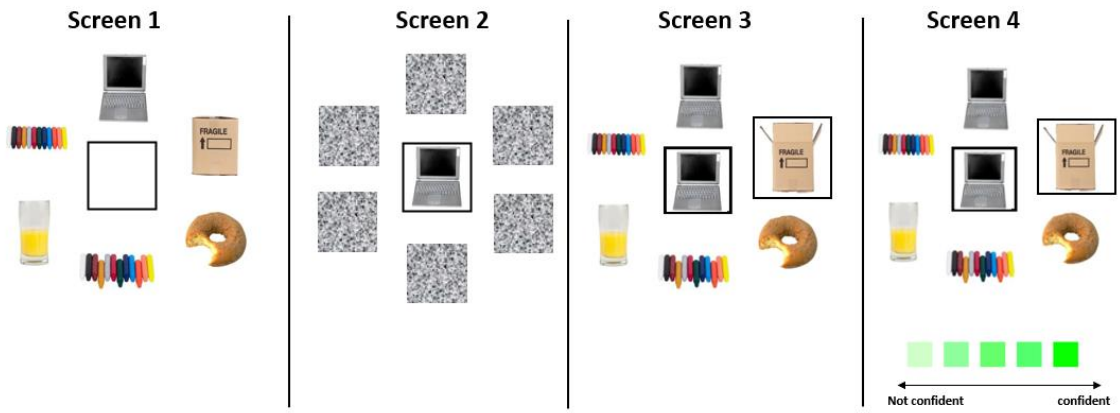


Table 1

Durations of the displays in a trial

Display	**Time of the displays in Ms**	
	Houter	**Piletti**
Pre-trial screen (blue square)	Until response	Until response
Blank screen	500	500
Reference screen (square)	100	100
Pre-change display	1000	1000
Interval before retro cue	400	400
Duration Retro Cue	**950**[a]	**250**
Interval after retro cue	0	750
Post-change display	Until response	Until response

[a] The cue remains visible until a response is given during the post-change display. Therefore, there is no interval after the retro cue. When the cue is presented, it takes 950 Ms before the post-change display appears.

Analysis

The raw data consists of the score of each participant on each trial. The data of the other studies in the larger study (Van den Brink, 2022; Griffiths, 2022; Martin, 2022; Piletti, 2022) is also included. The data will be aggregated and restructured in SPSS (IBM Corp., 2019) to compose the mean scores for each participant on each of the conditions, excluding the data from the other experiments and the excluded participants. So, each participant has four mean scores on each dependent variable (confidence and response accuracy). The main results will be analyzed in JASP (JASP Team, 2021) with a repeated measures ANOVA, since the participants participate in all conditions of the experiment. This analysis compares the different scores of the conditions with each other, giving a calculation for distance, target identity and an interaction between the two. Also, a paired samples t-test will be used to look at the influence of distance on the different levels of shared identity. This way, we get a closer look at the expected interaction between distance and target identity. The repeated measures ANOVA and the paired samples t-tests will be done for the scores on response accuracy and the confidence rating independently.

Another analysis will be done to see whether the results on an extended identity cue experiment (this study) differ from those on a non-extended identity cue experiment. For this analysis the results of Piletti (2022) will be used. Piletti (2022) describes another experiment of the larger study this thesis is a part of. Because of this, the experiments are similar, except for the duration of the cue (Table 1). The cue of Piletti (2022) is only visible during the mask and therefore non-extended, whereas the cue of this thesis is extended. For the analysis, the overall mean of each participant on response accuracy and confidence will be calculated from the aggregated dataset including the participants from both experiments. Afterwards, an independent samples t-test will be done to compare the means of both experiments on response accuracy and confidence.

Results

The results are analyzed with a repeated measures ANOVA, a paired samples t-test and an independent samples t-test. The assumptions for a repeated measures ANOVA are normality, sphericity and independent measures. As there are only two levels for both dependent variables, the sphericity assumption does not apply for this study. A paired samples t-test has the assumptions of normal distribution of the differences, independent subjects and the compared measures should be from the same person. An independent samples t-test has independent measures, normality of each group and homogeneity of

variances for the two groups. When one of these assumptions is violated in the analysis, it is mentioned in the results.

Response Accuracy

Response accuracy was measured as the proportion correct responses on the experiment. Since there were two answer options for each trial, a score of 0.5 was expected if someone guessed each time and had understood the instruction. It was expected that distance does have influence when target identity is shared, but not when it is non-shared (Hypothesis 1). For this interaction it was expected that people scored best on adjacent, identical objects. It also was expected that people would perform better if one of the identical objects was the target than when none of the identical objects was the target (Hypothesis 2). The descriptive statistics for response accuracy on the different conditions are shown in Table 2.

Table 2

Descriptive statistics response accuracy

Distance	Identity target	Mean	95% CI for mean		SD	N
			Lower	Upper		
Adjacent	Shared	0.803	0.756	0.851	0.135	34
	Non-shared	0.520	0.450	0.588	0.199	34
Non-adjacent	Shared	0.705	0.665	0.743	0.112	34
	Non-shared	0.462	0.390	0.533	0.204	34

Hypothesis 1 is not supported, as the results of the repeated measures ANOVA do not show a significant interaction effect between distance and target identity ($F(1,33) = 1.980$, $p = 0.169$, $\eta^2 = .002$). A paired samples t-test was conducted to get further insight in the non-occurrence of the interaction (Table 3). The assumption of equal variances was violated for the comparison of response accuracy in the shared identity condition. The Wilcoxon signed-rank test was used for that comparison. For both conditions of target identity, the effect of distance was significant. This suggests that distance has influence in both conditions of shared identity, with an adjacent identical object resulting in better scores than a non-adjacent one. This is not in line with the hypothesis, as it was expected that distance did not have influence in the non-shared condition. Therefore, the mean for the adjacent non-shared condition ($M = .520$, *95% CI* [.450; .588]) is higher than expected. However, for the shared identity condition, the hypothesis is supported. The effect of distance is significant in the shared identity condition, which suggests that people performed best when the target shared

identity and the identical object was placed adjacent (Figure 5). Which is in line with Hypothesis 1. The repeated measures ANOVA for response accuracy did show significant main effects for distance ($F(1,33) = 38.133$, $p < .001$, $\eta^2 = .033$) and target identity ($F(1,33) = 115.738$, $p < .001$, $\eta^2 = .375$). This suggests that people scored better when the target identity was shared and when the two objects sharing identity, not necessarily targets, were adjacent (Figure 5). Which is in line with Hypothesis 2.

Figure 5

Descriptive plots response accuracy and confidence level

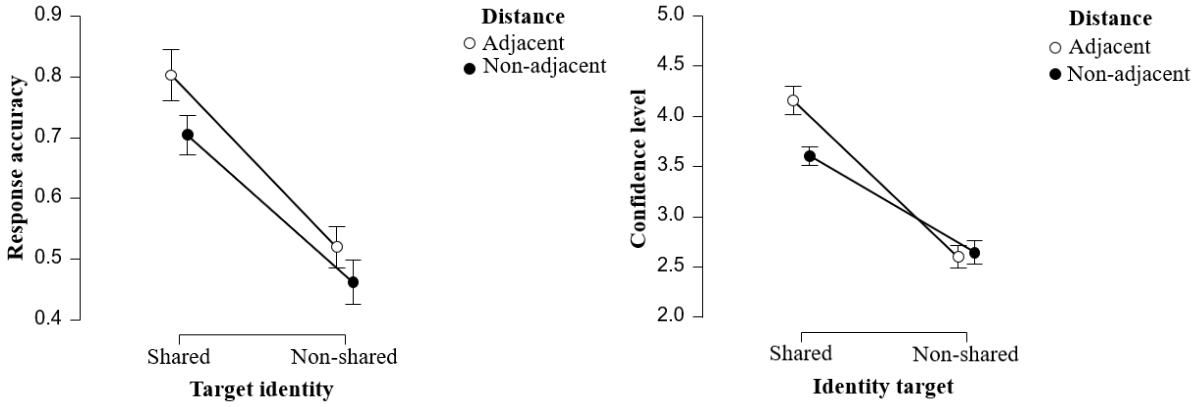


Table 3

Paired Samples T-Test

			Test	Statistic	Df	p
Correct mean.1.1	-	Correct mean.0.1	Student	-4.734	33	< .001
			Wilcoxon	42.500		< .001
Correct mean.1.0	-	Correct mean.0.0	Student	-3.324	33	0.002
Confidence mean.1.1	-	Confidence mean.0.1	Student	-9.515	33	< .001
Confidence mean.1.0	-	Confidence mean.0.0	Student	0.792	33	0.434

Note. The first digit represents distance (0 = adjacent, 1 = non-adjacent). The second digit represents target identity (0 = non-shared, 1 = shared)

Confidence Level for Response Accuracy

For the confidence level, it was expected that distance does have influence on how confident people are with their answer when the target shares identity but not when target identity is non-shared (Hypothesis 3). In the shared identity condition, it is expected that people will be most confident about detecting the right change when the target shares identity with an adjacent object. The descriptive statistics for confidence level are presented in Table

4. The repeated measures ANOVA showed a significant interaction between distance and target identity ($F(1,33) = 74.863$, $p < .001$, $\eta^2 = .023$). This is in line with Hypothesis 3. The paired samples t-tests (Table 3) were conducted to get more insight in the interaction effect. These t-tests show that distance did have a significant effect on performance when target identity was shared, but not when target identity was non-shared. This suggests that people in the shared condition were most confident when the objects were adjacent (Figure 5). In the non-shared condition, distance did not have an effect. This is in line with the expected interaction effect. The repeated measures ANOVA for the confidence level also gave significant main effects for distance ($F(1,33) = 35.851$, $p < .001$, $\eta^2 = .017$) and target identity ($F(1,33) = 226.783$, $p < .001$, $\eta^2 = .427$).

Table 4

Descriptive statistics confidence level

Distance	Identity target	Mean	95% CI for mean		SD	N
			Lower	Upper		
Adjacent	Shared	4.155	3.968	4.343	0.538	34
	Non-shared	2.601	2.315	2.887	0.819	34
Non-adjacent	Shared	3.607	3.393	2.934	0.614	34
	Non-shared	2.641	2.350	2.934	0.837	34

Extended identity cue

Hypotheses 4 and 5 are about the difference between an extended and non-extended identity cue. It is expected that people will perform better (Hypothesis 4) and are more confident (Hypothesis 5) on an extended identity cue experiment than on a non-extended identity cue experiment. The results of this study are compared with the results of Piletti (2022). The experiment of Piletti (2022) was similar to the one of this study only the identity cue was non-extended and therefore not present during the post-change display (Table 1). The descriptive statistics of both experiments are presented in Table 5. An independent samples t-test was performed to compare the mean scores for the two groups (Table 6). As the assumption of equal variances was violated, the Welch-test was performed. The results suggest that people scored better with an extended identity cue than with a non-extended identity cue, which supports Hypothesis 4. However, people were not more confident in the experiment with an extended identity cue, which means that hypothesis 5 is not supported.

Table 5

Group Descriptives

	Group	N	Mean	SD	SE
Correct mean	Piletti	34	0.559	0.116	0.020
	Houter	34	0.622	0.141	0.024
Confidence mean	Piletti	34	3.208	0.463	0.079
	Houter	34	3.251	0.652	0.112

Table 6

Independent Samples T-Test

	t	Df	p
Correct mean	-1.997	63.655	0.025
Confidence mean	-0.315	59.554	0.377

Note. Welch's t-test.
Note. For all tests, the alternative hypothesis specifies that group Piletti is less than group Houter.

Discussion

The main goal of this study was to get a closer look into the factors contributing to change blindness for state changes. Binding processes are related to change blindness (De Vries, 2004). Temporary neural connections between locations in the spatial map and identities in the cell assemblies are made because of serial binding processes. Because of these binding processes, an interaction between distance and identity of an object was expected for performance on a change blindness task (Hypothesis 1). The more the neurons in a cell assembly get activated, the higher the chance that its excitation level will reach the critical threshold making the temporary connection available in visual working memory. A cell assembly gets activated more when an object appears twice, instead of once, because it then has more connections to the spatial map that can activate the cell assembly. It was therefore expected that people had a better memory of an object when it appeared twice in the pre-change display, instead of once (Hypothesis 2). Distance was expected to have additional influence, as the binding process happens serially. Objects next to each other are bound directly after each other. Adjacent identical objects would then result in more activation of the cell assembly than non-adjacent objects, because the cell assembly is still activated from

the first object when it's additionally activated by an adjacent object. It was therefore expected that people would perform best if the target shared identity with an adjacent, rather than non-adjacent object. This effect for distance was not expected in the non-shared condition, because distance only influences the memory of the identical objects and in the non-shared condition the target is not one of the identical objects. People's confidence about their own performance was expected to be related to memory accuracy and was therefore expected to follow the expected interaction on response accuracy (Hypothesis 3).

Response accuracy and confidence

For response accuracy, the interaction of Hypothesis 1 was not found. Distance had influence in both the shared and non-shared condition. In both conditions participants scored best when distance was adjacent. So, a part of the interaction is supported, namely the influence of distance in the shared condition. The other part of the interaction is not supported, as no effect for distance was expected in the non-shared condition. The expected main effect for target identity of Hypothesis 2 was found. For the confidence level, the expected interaction of Hypothesis 3 was found: distance only had influence in the shared condition, resulting in the best performance when identity was shared and the shared object was adjacent.

The shared identity condition got the best scores. This is in line with binding processes leading to more activation of the temporary connection when the cell assembly is activated twice (De Vries, 2008). This increases the chance for the excitation level of the cell assembly to reach the critical threshold making the connection present in visual working memory. The serial binding theory (De Vries, 2008) is also supported because people scored better on adjacent identical images than non-adjacent ones. However, this also happened in the non-shared condition, whereas this wasn't expected. An alternative explanation can be given for this. In each trial there were two choice options. When people saw the change, they could choose the correct object. They could also choose the correct object when they noticed the other option (*non-target*) had not changed. So, if one of the identical objects was the non-target, distance might have had influence on performance. When adjacent objects are easier to remember than non-adjacent objects, people's memory of the non-target is better when it shares identity with an adjacent, instead of a non-adjacent object. This would make it easier to notice the non-target did not change, which made participants conclude the other object must have changed. This might have resulted in a better performance in the non-shared condition when distance was adjacent instead of non-adjacent.

However, it then would be expected that people would also be more confident in the non-shared adjacent condition than the non-shared non-adjacent condition, because they have a better memory of the identical objects. This was not found in the results because these supported the expected interaction in which distance had no influence in the non-shared condition. The response accuracy in the non-shared condition is around guessing rate. However, the confidence mean is around 2.6 on a five-point scale in that condition. This suggests that people overestimated their confidence, because a confidence of around one would be expected with a performance around guessing rate. This difference might have to do with overestimation of bad performances (Kim, et al., 2016). People overestimate bad performances because of two factors: the overall tendency to judge their own performance more favorable than it is, and relying less on their actual performance to determine their own ability when tasks are hard. The non-shared non-adjacent condition was the hardest condition. In that condition they might have used their own performance the least to determine their confidence, and therefore judged themselves much more favorable. This might have resulted in the relatively high confidence compared to the actual scores. For the easier categories, participants might have relied more on their actual performance to determine their confidence. This might have caused the overestimation to be bigger in the non-shared condition than in the shared condition.

Non-extended and extended identity cue

This study was compared with the experiment of Piletti (2022) that used a non-extended identity cue. As working memory is limited (Hartshorne, 2008), interference was expected to have influence in the non-extended identity cue experiment because people have to remember the cue, what might interfere with the memory of the pre-change display. This results in a worse memory of the pre-change display (Luck & Vogel, 2013). This is not the case for an extended identity cue experiment, as participants don’t have to remember the cue. It was therefore expected that people had better memory of the pre-change display with an extended identity cue instead of a non-extended one. Because of this better memory it was expected that participants in the extended identity cue experiment performed better (Hypothesis 4) and were more confident (Hypothesis 5) than participants in a non-extended identity cue experiment.

Participants scored better in the extended identity cue experiment, which supports Hypothesis 4. This supports the theory that interference (Luck, & Vogel, 2013) and secondary task performance (Marshev, Chetverikov & Kuvaldina, 2016) influence memory when the identity cue has to be remembered. There was no difference between the confidence

level of the two groups, as was expected in Hypothesis 5. The overestimation of our own performance on hard tasks might have played a role (Kim, et al., 2016). Also, the non-extended identity cue experiment might have been more difficult in general, people might have adjusted their ratings to this. They might have given a score of 3 out of 5 for an answer they were less sure about than a person in the extended identity cue experiment did, because their reference was different.

The larger study

The larger study consisted of four studies besides this one (Van den Brink, 2022; Griffiths, 2022; Martin, 2022; Piletti, 2022). Two looked at a non-extended identity cue (Van den Brink, 2022; Piletti, 2022), the others used a location cue (Griffiths, 2022; Martin, 2022). The results of the larger study all found the expected interaction for confidence, whereas for response accuracy the results were not in line. The non-extended identity cue studies did not find an interaction for response accuracy, as was the case in this thesis too. However, the studies using a location cue did find the expected interaction between distance and identity for response accuracy.

Limitations and future research

The study only had 34 participants who were mainly first year psychology students. Because of this, the external validity might be limited. Also, there were only two answer options in a trial. Therefore, we don't know if the effect for distance in the non-shared condition indeed is because of the identical objects being the non-target. Future research could focus on the influence of a non-target with a shared identity versus a non-target with a non-shared identity to see if there is an effect for a non-target sharing identity. Another interesting focus for future research is the overestimation of people's performance on hard tasks that appeared to be the case by looking at the confidence levels. It is also interesting to look at the difference between an identity cue and a location cue for performance on change blindness tasks. The results of this study give insight into the formation of visual memories. This study can be used for research on the relationship between brain damage and memory.

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Appendix A – Images used Grouped per Category

Storage






Household Appliances








Electronics

Entertainment

Drinks

Baking