The face you recognize may not be the one you saw: Memory conjunction errors in individuals with or without learning disability

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Abstract

Memory conjunction errors, that is, when a combination of 2 previously presented stimuli is erroneously recognized as previously having been seen, were investigated in a face recognition task with drawings and photographs in 23 individuals with learning disability, and 18 chronologically age-matched controls without learning disability. Compared to the controls, individuals with learning disability committed significantly more conjunction errors, feature errors (1 old and 1 new component), but had lower correct recognition, when the results were adjusted for different guessing levels. A dual-processing approach gained more support than a binding approach. However, neither of the approaches could explain all of the results. The results of the learning disability group were only partly related to nonverbal intelligence.

Keywords: Face recognition, memory conjunction errors, learning disability

Author note

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The Face You Recognize May Not Be the One You Saw: Memory Conjunction Errors in Individuals With or Without Learning Disability

Memory conjunction errors represent a form of memory illusion (see Roediger, 1996, for an overview) in which individuals erroneously recognize a stimulus as "old", though it is a combination of two previously presented stimuli. One example of a memory conjunction error is that subjects studying lists with compound words like "Heartache" and "Toothpaste" have a strong tendency to claim that test words like "Toothache" have been seen before (Reinitz & Demb, 1994). This effect has been shown for many different types of stimuli, for example, nonsense words (Reinitz, Lammers, & Cochran, 1992; Reinitz & Hannigan, 2001), real words (Reinitz, Verfaellie, & Milberg, 1996; Rubin, Van Petten, Glisky, & Newberg, 1999; Marsh, Hicks, & Davis, 2002, Jones & Jacoby, 2001; Jones, Jacoby, & Gellis, 2001), sentences (Reinitz et al., 1992), colors (Zimmer & Steiner, 2003), environments with landmarks (Albert, Reinitz, Beusmans, & Gopal, 1999), autobiographical events (Odegard & Lampinen, 2004), drawings of faces (Reinitz et al., 1992; Kroll, Knight, Metcalfe, Wolfe, and Tulving, 1996), and photographs of faces (Bartlett, Searcy, & Abdi, 2003; Busey & Tunnicliff, 1999). There have also been some studies of special populations, for example individuals with amnesia (Reinitz, Verfaellie, & Milberg, 1996), individuals with hippocampal damage (Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996; Stark & Squire, 2003), and older adults (Rubin et al., 1999), but none with individuals with learning disability.

The purpose of the present study was to compare two main competing theoretical explanations of memory conjunction errors, the *dual-processing approach* (e.g.

Bartlett et al., 2003; Jones & Jacoby, 2001; Jones et al., 2001) and the *binding approach* (e.g. Kroll et al., 1996; Reinitz et al., 1992; Reinitz et al., 1996), in a group of individuals with learning disability and in a group of chronologically age-matched controls. Individuals with learning disability were chosen since it is a well established fact (for a review on cognitive competences and strategy use in persons with learning disability see Wyatt & Conners, 1998) that they, unlike individuals without learning disability, demonstrate problems in a wide range of tasks requiring the use of controlled (i.e. Bray, Fletcher, & Turner, 1997) or strategic processing (i.e. Brown 1974). However, they are equally successful on memory tasks tapping automatic processing (i.e. picture fragment completion task in Bray, Fletcher, & Turner, 1997). In our interpretation of the two theoretical approaches, this leads to different predictions since the dual-processing approach assumes one component with controlled strategic processing (i.e. recollection) and one component tapping automatic processing (i.e. familiarity), whereas the binding approach assumes two components tapping automatic processing as an explanation of memory conjunction errors. In other words, individuals with learning disability will depend on the automatic processing familiarity component to a higher degree, which makes testing of the dual-processing approach more precise.

When testing memory conjunction errors, besides conjunctions, old stimuli (previously shown) and new stimuli (previously not shown) are always used to get comparison data. Another type of stimuli called features, that are composed of a part that is previously shown and a part that is previously not shown, is sometimes also used. This kind of stimulus is included in the present study since the two theoretical approaches lead to different predictions regarding features. The performance for new test pictures is in our study considered as a base-line that is subtracted from the other types of stimuli. This base-line is used to adjust the results for different guessing levels, and also for group differences unrelated to the components of the two competing theoretical approaches. The performance for the other types of pictures are called adjusted hits, adjusted conjunction errors, and adjusted feature errors, when the performance for new pictures have been subtracted from them.

Type of Stimulus Material

The material used in the present study consists of drawings of faces and photographs of faces. Photographs are ecologically interesting since they also are used for purposes of augmentative and alternative communication for the learning disability group (cf. Danielsson, Rönnberg & Andersson, 2004, 2006).. Kroll et al. (1996) demonstrated low performance for individuals with left or right hippocampal brain damage for one type of face drawing stimuli, and argued that many and complicated facial features with high similarity would cause more errors to be made. Mirenda and Locke (1989) found that for individuals with learning disability, photographs had the highest transparency of different symbols, that is, they were easiest to match with a real object. Actually, the transparency in general decreased as the symbol looked less and less like the object they depicted, and as abstraction increased. Even though the first study was conducted on a different population and the second study with a different task than the present study, they lead to different predictions regarding the error rates for relatively abstract drawings with few features on the one hand and non-abstract photographs with relatively many and complicated features on the other. Photographs are predicted to lead to higher error rates than for drawings, if the number and the complexity of the features of a stimulus are important (in line with Kroll et al., 1996), or to lower error rates if the level of transparency of stimulus is important (in line with Mirenda & Locke, 1989).

Face perception is of holistic nature (Carey & Diamond, 1977, 1994). Faces have an inherently cohesive property that for example nonsense words lack. Therefore, Reinitz et al. (1992) proposed that using faces offers a more rigorous test of memory conjunction errors. According to Reinitz et al., faces are of interest because they represent an ecologically valid type of stimulus and because of the obvious real-world significance of the research, for example, when applied to eyewitness testimony. With respect to our special population, it is also important to reduce interference with other potentially impaired abilities, such as reading ability that is known to vary in individuals with learning disability.

The binding approach and the dual-processing approach

Components and configurations are two types of representations proposed by the binding approach (e.g. Kroll et al., 1996; Reinitz et al., 1992, 1996). Components, which are considered as lower-level representations, may be bound together to form more global or configurative representations. It is suggested that recognition of old stimuli is based on both components and configurations. Conjunction errors are thought to be based either on (a) the stored components of the stimuli in absence of the relationship between components (Reinitz et al., 1992, 1996), or (b) on an inaccurate encoding of the relationship (Kroll et al.). The first alternative implies that conjunction errors occur since a configurative representation is inaccessible while the second implies that the components of the stimuli are incorrectly bound in the study phase (Kroll et al.).

Kroll et al. (1996) suggested that two mechanisms in the hippocampus are involved in the binding process, a binding mechanism and a binding mechanism inhibitor. The binding mechanism permits the individual to bind components of the stimuli together, correctly or incorrectly. The binding mechanism inhibitor, on the other hand, protects the individuals from inappropriately binding elements that do not belong together. When conjunction errors occur, the binding mechanism inhibitor fails to hold the binding mechanism under control.

According to the dual-processing approach, recollection and familiarity offer independent bases for responding in a memory task. Familiarity is believed to be a relatively fast and automatic process that gives a feeling of having seen something before without the possibility to consciously recollect, while recollection is thought to be a relatively slow, controlled strategic process that includes the conscious reexperiencing of the item. Familiarity with components at recognition may cause the individuals to erroneously believe that they recognize features and conjunctions. Recollection of the encoded stimuli can help the individuals to avoid such false recognition.

The binding approach and the dual-processing approach therefore offer different predictions in a number of respects:

1) The dual-processing approach predicts that *twice as many adjusted conjunction errors compared to adjusted feature errors* will be committed. This is because conjunctions have two old components compared to only one for features. The binding approach predicts that there will be *more adjusted conjunction errors than adjusted feature errors*. The binding mechanism binds together a picture, and since, in conjunctions all parts of the picture have been seen before, they are likely to be erroneously recognized, whereas for features this is impossible since it includes a new part that has not previously been seen. More than twice as many conjunction errors compared to feature errors have been found in some studies (Reinitz et al., 1992, Experiment 5, Kroll et al., 1996; Reinitz et al., 1996) and less than twice as many in others (Rubin et al., 1999, Odegard & Lampinen, 2004). Brain activity data

(Rubin et al.) have not revealed any difference between processing conjunctions, features or new stimuli. Thus, results are obviously mixed at this point.

2) The dual-processing approach predicts that there will be *more falsely recognized features than new pictures*, because features have a previously seen component. The binding approach predicts that there will be *no difference between feature errors and errors committed to new pictures*, henceforth called false alarms. Jones and Jacoby (2001) evaluated eight studies and found that in 43 out of 46 conditions there were more feature errors than false alarms, but the difference was not necessarily statistically significant. A significant difference in the predicted direction was found in one out of six manipulations included in a test to reduce conjunction errors (Lampinen, Odegard, & Neuschatz, 2004). Rubin et al. (1999) found the predicted statistical difference in one out of two experiments. Thus, most studies found a difference, but only a few found a statistically significant difference. Further research is needed.

3) Individuals with learning disability, compared to individuals without learning disability, typically demonstrate problems in tasks requiring the use of controlled strategic processing but not in memory tasks tapping automatic processing (i.e. Bray et al., 1997; Wyatt & Conners, 1998). The binding approach assumes that there are two components, the binding mechanism and the binding mechanism inhibitor, and that both of them are automatic. Therefore, the binding approach leads to the prediction that there will be *no difference between the groups at any recognition type*.

The dual-processing approach assumes one component with controlled processing, recollection, and one component using automatic processing, familiarity. For hits, both recollection and familiarity can help to remember the target (Jones & Jacoby, 2001). For conjunctions and features, familiarity is making one to commit errors (Jones & Jacoby, 2001) whereas recollection can both give rise to and prevent errors (Lampinen, Odegard & Neuschatz, 2004). Recollection rejection (Brainerd & Reyna, 2002; Brainerd, Wright, Reyna & Mojardin, 2001) is when a related lure is rejected because the target is consciously recollected, and phantom recollection (Brainerd et al., 2001; Lampinen, Odegard & Neuschatz, 2004) is when false memories are experienced in a surprisingly compelling form. Lampinen et al. (2004) have found both of these types of recollection for conjunctions and features. Since persons with learning disability have, compared to a control group without learning disability, intact automatic processing but impaired controlled processing, as stated above, the dual-processing approach predicts that *the learning disability group will, compared to the controls, make less adjusted hits, more adjusted conjunction errors and more adjusted feature errors*.

Finally, intelligence and learning disability are strongly correlated. Therefore, nonverbal testing of intelligence is included in the study as a more accurate means of measuring whether intelligence estimates provide better predictions of the error types under scrutiny than the group categorization per se.

Predictions

This study is an attempt to replicate Experiment 2 in Kroll et al. (1996), using another population and a new type of material. The predictions are summarized below.

(1) The binding approach predicts that (a) more adjusted conjunction errors than adjusted feature errors will be committed, (b) there will be no difference between the amount of adjusted feature errors, and (c) that there will be no group differences. In contrast, (2) the dual-processing approach predicts that (a) twice as many adjusted conjunction errors as adjusted feature errors will be committed (b) more feature errors

than false alarms will be committed, and (c) the learning disability group will, compared to the controls, make less adjusted hits, more adjusted conjunction errors and more adjusted feature errors. (3) Regarding materials, there are two opposite predictions. If the complexity of the features of a stimulus is important, there will be (a) more errors for photographs, but if the level of transparency is important there will be (b) more errors for drawings.

Method

The method was similar to the one used in Kroll et al. (1996, Experiment 2), however it was adapted to participants with learning disability after two series of pilot testing. A detailed description of the method is provided below, but the general adaptations are first described as an overview.

The instructions were simplified. A pretest including a perceptual task with a design similar to the main task, and a practice round of the main task including feedback regarding response accuracy were provided with the adapted design. To more clearly mark the boundaries of the pictures, all pictures were framed. A guitar sound was presented during encoding of each picture to help the participant to focus their attention on the screen. The time between encoding and retrieval, which in Kroll et al. (1996) included a filler task, was excluded since hit rates compared to false alarms on pilot testing were too low. The task where the participants judge their confidence about their responses used by Kroll et al., was excluded due to the fact that the participants with learning disability could not all fully comprehend the meaning of "confidence rating".

Participants

All participants in the experimental group had learning disability and could communicate through spoken language. To eliminate participants who either claimed to recognized all or none of the test faces at recognition from the analysis, the signal detection theory score *d′* (see Green & Swets, 1966, for an introduction, and Corwin, 1994; Snodgrass & Corwin, 1988 for more updated methodological discussion) were calculated for each participant. Five participants with a d' score less than 0.5 were excluded from the study.

A total of 23 participants, 13 female and 10 male with an average chronological age of 36.3 (*SD* = 9.3) years, were recruited from an educational program for individuals with learning disability in Sweden. Raven's coloured matrices (Raven, Court, & Raven, 1995) were used to assess a measurement of nonverbal intelligence. Eight individuals did not achieve the criteria for having a valid score according to the manual (Raven et al., 1995), and are said to not have grasped the nature of the test. The mean of their invalid raw score was 12.3 (*SD* = 5.4). The other 15 individuals had a mean of 20.4 (*SD* = 5.6) correct answers. The control group consisted of 18 individuals, 10 female and 8 male, without learning disability and with an average chronological age of 37.8 (*SD* = 9.9) years. Their nonverbal intelligence score was 34.2 (*SD* = 1.9). The control group was matched to the learning disability group on average chronological age and sex.

Tasks

The experiment consisted of three parts: pretests, the main task, and the intelligence test.

In the first part of the pretests the participants were to judge if two simultaneously presented faces were identical or not. The second part was to judge if one picture was identical with four other simultaneously presented pictures. The third part was the same as the second with the difference that it was a recognition task instead of a matching task. The pretests were designed with two intentions: 1) to start with a basic skill and gradually raise the level of task difficulty on the way to a task similar to the main task. This was done to ensure that the participants had the skills needed to cope with the main task, and 2) to train the procedure used in the main task.

A facial memory task with the intention to investigate memory conjunction errors was the main task. The participants' nonverbal intelligence was tested with Raven's Coloured Progressive Matrices (Raven et al., 1995), with the purpose of investigating whether it could be a suitable predictor of conjunction errors. The procedure followed the manual.

Stimulus material

Pretests. All participants received exactly the same set of drawings of faces in the pretests. In the first pretest task 10 pairs of faces were used; five pairs where the faces were the same, three pairs where the faces were totally different, and two pairs where the faces had one component in common.

In the second pretest task the six test figures included one conjunction, one feature, one totally new face, and three faces that were identical to three of the study faces.

The third pretest task included two sets of pictures with different face drawings, which each was composed of a study-subset and a test-subset. The study-subsets contained four faces each and the test-subsets contained six faces each; three old pictures, one conjunction, one feature, and one new picture. The proportion of each recognition type was chosen so that there should be the same proportion of "same" and "different" answers. This was made to preclude a bias to any of the answers. To make the participants aware of the fact that the parts that constituted the face component sets could be different, the face component sets in the two sets consisted of different parts. For example, in one set one face component set consisted of the hair and shape of the face and in the other set, one face component set consisted of the hair, shape of the face, and eyebrows.

Main task. As for the picture sets in the third pretest task, in the main task each set was also composed of a study-subset and a test-subset. Each face was presented in the middle of the screen on a white background with a black frame. In the main task photographs were also used. To increase the statistical power in the experiment, four different face categories of photographs were created, namely females in color, females in black and white, males in color, and males in black and white. The categories were intended to be dissimilar to each other, to avoid interference between the different face categories. The photographs were made by morphing pairs of photographs in Adobe Photoshop 5.5, see Figure 1 for an example. All photographs used, including the old and new category, were morphed photographs to avoid that the subjects identified photographs that looked morphed, instead of performing the intended recognition task.

Figure 1. An example of how morphed photographs were created using photos of two of the authors. The inner parts of the photo to the left together with the outer parts of the photo in the middle form the photo to the right, which is a conjunction picture.

The same six face categories used by Kroll et al. (1996), where example pictures can be seen, were used together with the four categories with photographs and were presented in the same order for all participants: cartoon faces, photos of females in color, circle faces, photos of females in black and white, simple drawings of female faces, photos of males in color, egg faces, photos of males in black and white, simple drawings of male faces and, complex line-sketch faces.

The 10 face categories contained five faces within each study-subset, and eight faces within each test-subset. These eight faces were related to the study faces in the following ways: two of the test faces were identical to two of the study faces, two of the test faces were conjunctions of the face component sets of two of the study faces, two of the test faces had one of the face component sets of a study face and one face component set that did not appear on any of the study faces, and two test faces were completely new. The proportion of recognition types were optimized to the analysis of variance (ANOVA) to be used so that each recognition type were shown equally many times and consequently had the same number of replications.

The main difference from the Kroll et al. (1996) experiment, regarding the drawings, was that one additional set of study and test faces for each category was created to eliminate material effects. Due to the lack of existing similar pictures and the impossibility to create pictures in the same style, another path was taken. Instead, the two new faces in the first test-subset became members of the second study-subset, and consequently, two of the study faces in the first study-subset became new faces in the second test-subset. Further, the study faces that formed the various recognition types in the respective test-subset differed between the two sets. All the test faces consisted of two parts taken from the study faces. With parts from three study faces two conjunction stimuli were made and the remaining two parts along with two new parts formed the two feature stimuli. The other two study faces formed the two old test faces.

The order and placement of the study faces were balanced through the different face categories. They were also balanced for order and placement between the two different sets of each category. To avoid order effect among the pictures within a set, two different orders were used; namely, forward and backward. Both the learning disability group and the control group were divided into four subgroups, matched by average age and sex, who conducted the task in one out of four different combinations of material and orders.

Procedure

All tests, except the intelligence test, were completed on a Hewlett Packard Omnibook 6000 computer. The tasks were distributed in two to four sessions, depending on how fast the participants completed the tasks, how tired they became, and their ability to focus on the tasks. Each session lasted on average 30 minutes.

All participants were instructed that a test stimulus only was the same as a study stimulus if both face component sets were repeated and paired in the same way as they had been in the original study set. Because of the differences between the participants' ability to handle the computer mouse, the test leader handled the mouse and the participants were asked to say "same" or "different" when they saw each test face, or if they had a problem with that, they were to answer "yes" or "no". For practical reasons, not all sessions could be completed in the same day. To compensate for that, if the second to fourth session took place on another day, it always started with the third part of the pretests.

Pretests. In the first part of the pretests the participants were to judge if two simultaneously presented faces were identical or not. Each face was presented in a white square with a black frame. The face to the left was presented on a red background, and to the right on a blue background.

After that, they continued with the second part of the pretests in which four study faces were shown during the whole time and the test faces were presented sequentially. The participants were asked to judge if the test face was identical to any of the study faces. If the individual answered incorrectly, the test leader provided the correct response and pointed out the differences or similarities. The four study faces were all presented to the left in a white square on a red background. Test faces were shown to the right in a white square with a black frame on a blue background.

In the third pretest task, the study faces appeared on the screen for 10 s per figure during the first trial, then 5 s each during the second and third trials. Immediately after the study phase, the test phase followed. The test figures appeared sequentially and the participants were to judge if they had seen the face or not. If the individual gave an incorrect response, a feedback was given: The four study faces and the specific test face were shown and the instructor asked the individual to judge if the test face was the “same” as any of the study faces or “different” than all of them. If the individual, once again, answered incorrectly, the test leader provided the correct response and pointed out the differences or similarities. The third pretest consisted of two repetitions of the same task with different pictures and these tasks were completed immediately after each other.

Each face was presented in the middle of the screen on a white background with a black frame. To help the participants to focus on the task, a guitar melody was played during the study phase. The melody started over every time the picture changed and by listening to the melody, the participants could “hear” how much time was left until the picture changed.

Main task. The procedure for the main task was the same as for the third pretest task except that no feedback was shown even if the participants gave an incorrect answer, which the participants were also informed of.

Design

The design of the analysis of the main task was a 2 x 2 x 3 split-plot factorial design. The first factor refers to the between-subjects variable group (participants with learning disability or the control group). The second factor refers to the within-subjects variable material (drawings or photographs). The third factor refers to the within-subjects variable recognition type (adjusted hits, adjusted conjunction errors, or adjusted feature errors).

Result and Discussion

In all analyses the dependent variable was recognition of faces in percent (scored as 100 if the individual recognized the face, i.e., for old pictures it was a correct answer but for conjunctions, features and new pictures it was an error). Scoring correct answers instead would give another interaction pattern, but since we are not interested in the interaction per se, but only in its relation to the two theoretical approaches, the scoring method is not critical.

First, the results of the main task for drawings are presented with comparisons with the Kroll et al. (1996, Experiment 2) and Reinitz et al. (1992, Experiment 6) studies. This is done to validate that the present test measures the same phenomenon. Second, a full analysis with all the three variables is presented. Third, the predictions are investigated with a priori comparisons, before the effect of intelligence scores on memory conjunction errors is investigated. All dependent variables were analyzed with ANOVA, except the effect of intelligence scores which was analyzed with analysis of covariance (ANCOVA). All a priori and posteriori mean comparisons were made with *t* tests, using pooled error terms where appropriate (Kirk, 1995). The alpha level was set at .05 for all statistical tests used throughout the study. In the comparison with the Kroll et al. (1996, Experiment 2) and Reinitz et al. (1992, Experiment 6) studies new pictures are considered to be a recognition type condition to be able to compare the results in the same way. For the ANOVA, however, the results for new pictures is subtracted from the other conditions, which henceforth are called adjusted hits, adjusted conjunction errors and adjusted feature errors.

Table 1 presents the average percentage of recognized faces for the two groups for each recognition type of drawings for the face category with the complex line-sketch faces compared with the results from Kroll et al. (1996, Experiment 2) and Reinitz et al. (1992, Experiment 6).

The main difference in test procedure between the different studies was that, whereas Kroll et al. (1996) had a 10 min filler task and Reinitz et al. had a 45 min filler task, the participants in the present study completed the test immediately after the study phase. As in the Kroll et al. study the participants in the present study saw the faces in three study trials of 10, 5, and 5 s per face, whereas in the Reinitz et al. study the participants saw the faces in a single study trial of 30 s per face. The absence of a filler task may explain why the control group in the present experiment committed fewer conjunction errors compared to the participants in the Kroll et al. and Reinitz et al. studies. This may also explain why only the students in the study by Kroll et al. committed fewer conjunction errors than the learning disability group. However, the filler task did not seem to affect the amount of feature errors, since the control group in the present study committed as many feature errors as the students in the Reinitz et al. study.

Table 1: Average percentage of recognized faces for the groups for each recognition type for the face category with the complex line-sketch faces.

Participants	Old	Conjunction	Feature	New
	Present study			
Learning disability	70.5	47.7	34.1	31.8
Control	88.5	26.9	19.2	7.7
	From Kroll et al. (1996, Experiment 2)			
Students	91.7	40.3	11.1	2.8
Older Adults	80.6	66.7	25.0	5.6
Right hippocampal damage	78.6	64.3	42.9	21.4
Left hippocampal damage	64.3	78.6	35.7	14.3
Bilateral hippocampal damage	100.0	100.0	50.0	50.0
	From Reinitz et al. (1992, Experiment 6)			
Students	71	53	19	13

Table 2 presents the average percentage of recognized faces for the two groups for each recognition type for the remaining five face categories of drawings compared with the results from Kroll et al. (1996, Experiment 2).

The main difference in test procedure between the different studies was that Kroll et al. (1996) had a 10 min filler task between the study and test phase of Cartoon faces, whereas the participants in the present study performed the test immediately after the study phase for all face categories. Both groups in the present study performed at a lower level than the students in the study by Kroll et al., though, the control group performed at a similar level to the older adults. On the other hand, the two groups with left and right hippocampal damage outperformed the learning disability group in the present study. However, the general pattern of results in the present study is similar to the pattern in the Kroll et al. study, which leads to the conclusion that despite the methodological adjustments made in the present study, the same phenomenon is investigated.

Table 2: Average percentage of recognized faces for the groups for each recognition type for the remaining five face categories of drawings.

Participants	Old	Conjunction	Feature	New
Present study				
Learning disability	83.6	61.8	28.6	17.3
Control	90.0	31.5	1.5	2.3
From Kroll et al. (1996, Experiment 2)				
Students	95.6	7.2	.6	2.5
Older Adults	96.7	30.5	6.1	0.0
Right hippocampal damage	100.0	58.4	12.5	1.3
Left hippocampal damage	100.0	56.4	10.7	7.2
Bilateral hippocampal damage	100.0	100.0	25.0	0.0

An analysis of the variables used for counterbalancing, material and order, showed that there were no significant differences in results between the four subsets. Thus, there were no material or order effects. Further, there were no significant differences between the different face categories. Due to this, in the further analyses data were collapsed across the four subsets and across the six face categories.

There was a significant main effect of recognition type, $F(2, 78) = 402.78$, $p < .001$, partial $\eta^2 = .91$, and the responses of recognition differed significantly between all the types (adjusted hits, adjusted conjunction errors, and adjusted feature errors), all *p*s < .01. There was also a significant effect of group, $F(1, 39) = 82.98$, $p < .001$, partial $\eta^2 = .68$, the learning disability group had a higher mean (45%) compared to the control group (37%). Further, there was a significant effect of material, $F(1, 39) = 4.98$ $p < .05$, partial $\eta^2 = .11$, where photographs were claimed to have been seen more. The recognition type by group interaction was significant, $F(2, 78) = 46.76$, $p < .001$, partial $\eta^2 = .55$, as well as the recognition type by material interaction, $F(2, 78) = 7.17$, $p < .01$, partial $\eta^2 = .16$, and the group by material interaction, $F(2, 39) = 11.88$, $p < .01$, partial $\eta^2 = .23$. The 3-way interaction was not significant, but is shown in Figure 2 to get an overview of the 2-way interactions.

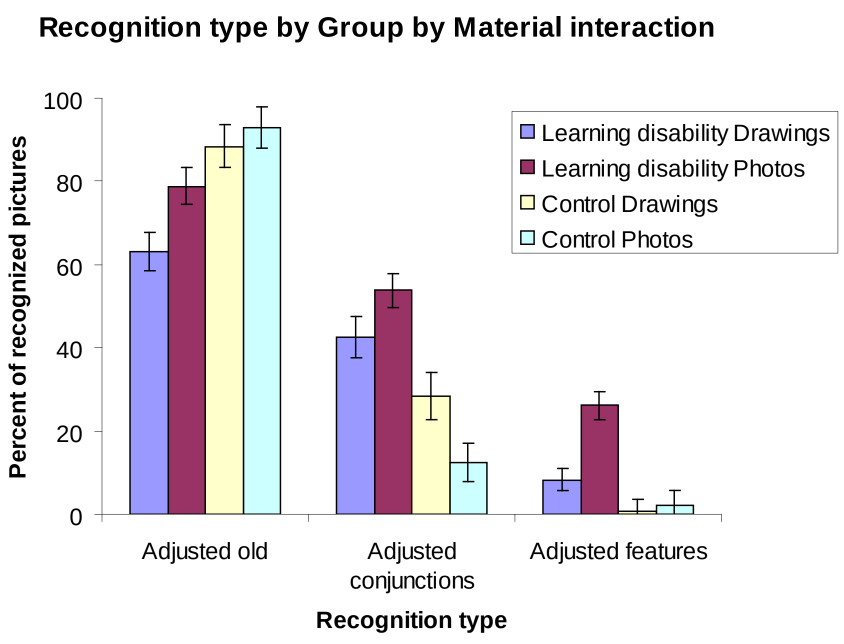

Figure 2. Recognition type by group by material interaction in the ANOVA on recognized pictures with standard error marked on the bars.

A priori tests showed that the learning disability participants committed more than twice as many adjusted conjunction errors (45%) than adjusted feature errors

(15%) (a comparison with *t*-test where adjusted conjunction errors were compared with adjusted feature errors multiplied by two), $t(78) = 2.59$, $p < .05$, and for the controls, there were more than twice as many adjusted conjunction errors (21%) compared with adjusted feature errors (5%), $t(78) = 3.28$, $p < .01$. Both groups performed in line with the binding approach.

There were significantly more feature errors than false alarms (i.e. higher adjusted feature level than zero) for the learning disability group, $t(78) = 5.05$, $p < .001$, but not for the controls. The results for the LD group support the dual processing in favor of the binding approach, whereas the opposite is true for the controls.

A priori tests showed that participants with learning disability, compared to the control group, made significantly less adjusted hits, $t(117) = 3.90$, $p < .001$, more adjusted conjunction errors, $t(117) = 5.47$, $p < .001$, and more adjusted feature errors, $t(117) = 3.12$, $p < .01$. These results are in line with the dual processing approach, but not the binding approach.

In addition, the difference between adjusted hits and adjusted conjunction errors were calculated. This gives a measure of the configuration-based processing. There was a group difference, $t(117) = 9.33$, $p < .001$, where the controls used more configuration-based processing.

A priori comparisons of material effects in the learning disability group revealed significant differences for all recognition types, all *p*s < .001, where photographs were more recognized. In the control group, there were significant differences for adjusted hits and adjusted conjunction errors, all *p*s < .05, where photographs lead to more adjusted hits and less adjusted errors. These mixed results are also mixed in relation to predictions.

In a further analysis the effect of nonverbal intelligence on recognition was studied with an ANCOVA. Since there was a ceiling effect in the nonverbal intelligence score in the control group, only the learning disability group was included in the analysis. There was no effect of or interaction with nonverbal intelligence. A subgroup division based on whether a valid score on the nonverbal intelligence test was obtained or not (according to the manual), gave no significant subgroup difference or any subgroup by recognition type interaction. Thus, nonverbal intelligence is not suitable as a measurement to predict errors in memory conjunction experiments within the learning disability group.

A further ANCOVA with reaction time was also made to investigate if some of the ANOVA effects could be attributed to picture viewing time. The only difference was that the material by recognition type interaction was no longer significant, but the patterns of this and the other significant results did not change compared to the main ANOVA.

To summarize, the results supported the following predictions derived from the binding approach: 1) more adjusted conjunction errors than adjusted feature errors for both groups, and 2) no difference between the amount of feature errors and false alarms for the controls. Results not in line with the predictions were a) group differences for the amount of adjusted hits, adjusted conjunction errors, and adjusted feature errors and b) a difference between the amount of feature errors and false alarms for the learning disability group.

The results supported the following predictions derived from the dual-processing approach: 3) a difference between the amount of feature errors and false alarms for the learning disability group and 4) group differences for adjusted hits, adjusted conjunction errors, and adjusted feature errors. Results not in line with the predictions were c) more than twice as many adjusted conjunction errors as adjusted feature errors for both groups, and d) no difference between the amount of feature errors and false alarms for the controls.

The hypothesis regarding material effects, that the level of transparency is important receives support in one out of four conditions, where photographs produced less errors, and the hypothesis that complexity is important receives support in two out of four conditions, where photographs produced more errors. Furthermore, the results suggest that nonverbal intelligence is not suitable as a measurement to predict errors in memory conjunction experiments within the learning disability group.

General Discussion

The purpose of the present study was to compare two theoretical explanations of memory conjunction errors, the dual-processing approach and the binding approach. This section is organized in such a way that methodological issues, like the effect of stimulus type and intelligence, are discussed first. Then a more theoretical discussion of the two approaches is presented. Finally, a comparison between the results of the learning disability group and the results in the study by Kroll et al. (1996) is made.

Methodological issues

Stimulus type. Kroll et al. (1996) argued that many and complicated facial features with high similarity lead to more errors, whereas the results of Mirenda and Locke (1989) could be interpreted in terms of abstract pictures leading to more errors. The results in the present study are mixed regarding which hypothesis is the best. Since the LD group made more false alarms to drawings, there is a generally lower performance for the adjusted recognition types since the amount of false alarms is subtracted from each score. Therefore, depending on how to conceptualize the results, it can be said that photographs lead to fewer false alarms or that photographs lead to a higher degree of recognized pictures, independent of whether they have been seen before or not for the LD group. For the controls, the results are mixed independently of how they are conceptualized.

Intelligence. The ANCOVA analysis showed no effect of nonverbal intelligence within the learning disability group. However, the main analysis showed that there were differences between the participants with learning disability and those without, and there is clearly a difference regarding nonverbal intelligence between the groups. This suggests that nonverbal intelligence alone is not sufficient to predict performance in memory conjunction errors tasks. Another conclusion is that since there was no interaction with nonverbal intelligence for recognition type in the ANCOVA, if the effect of nonverbal intelligence is true, it does not hold selectively for any recognition type. Only one test was used to measure intelligence. To be able to draw stronger conclusions about the relationship between intelligence and errors in memory conjunction experiments, a more extensive measurement of each participant's intelligence must be made, however, this was beyond the scope of the present study.

Comparison of Theoretical Approaches

Binding. The binding approach predicted that (a) more adjusted conjunction errors, compared to adjusted feature errors, would be committed, (b) there should be no difference between the amount of feature errors and false alarms, and (c) no group differences for any recognition type. The results seem to fit the binding approach well for prediction (a), partly for prediction (b) where only the controls performed in line with the prediction, but this was probably due to a floor effect. However, the results concerning the relationship between the controls and the learning disability group (c), are not in line with the binding approach.

As was stated in the introduction, individuals with learning disability, compared to individuals without learning disability, have relatively impaired controlled strategic processing but intact automatic processing (i.e. Bray, Fletcher, & Turner, 1997; Wyatt & Conners, 1998). Therefore, the group difference is probably due to some mechanism using controlled processing. It can be argued that some explicit process have influenced our results, like for example attention. Reinitz, Morrissey, & Demb (1994, Experiment 2) showed that with varying degrees of attention (divided versus full) in a memory conjunction experiment, the performance was impaired such that the number of hits was lower, and the number of conjunction errors, feature errors and false alarms were higher in the divided condition compared to the full attention condition. Because persons with learning disability generally perform lower in attention-demanding tasks (Sterr, 2004), they may be more easily distracted at encoding. If the encoding had been compromised for persons with learning disability in the present study, this should have lowered the performance in all the conditions. However, the false alarm rate is subtracted from all the other for the adjusted recognition types, and since there is no reason to believe that attention would be different for different recognition types, this threat to validity can be ruled out. To be able to explain the results in the present study, the binding approach needs one (or more) new component(s) as a complement to the two existing ones. The new component(s) should be active for all recognition types, should use controlled processing, and should differentiate between features and new pictures. To summarize, the binding approach can explain some of the data, but a new component must be added if all of the present results are to be explained.

Dual-processing. The dual-processing approach predicted that (a) twice as many adjusted conjunction errors as adjusted feature errors would be committed (b) more feature errors than false alarms would be committed, and (c) the learning disability group will, compared to the controls, make less adjusted hits, more adjusted conjunction errors and more adjusted feature errors. The present results demonstrate that prediction (a) is not supported for any group, whereas (b) is supported for both groups, if a probable floor effect is taken into account, and (c) is fully supported. It can be argued that the prediction of twice as many adjusted conjunction errors as adjusted feature errors relies on an excessively mechanical interpretation of the approach, since it is based on the view that the recollection component prevents errors equally much for conjunctions and features. A recent study (Lampinen, Odegard, & Neuschatz, 2004) showed that there were both more phantom recollection and recollection rejections for conjunctions compared to features. However, taken into accounts both recollection rejection and phantom recollection, the total effect of the recollection component prevents more errors than it creates for both conjunctions and features, and is bigger for conjunctions. This is line with the results in the present study. Therefore it can be argued that the interpretation was too mechanical. Moreover, the prediction in a nonmechanical interpretation would be less specific, just predicting more adjusted conjunction errors than adjusted feature errors, which is actually the same as for the binding approach. This prediction is in line with the results.

Conclusion of the Comparison. The dual-processing approach can explain most of the results in the present study. The other results can be explained with a floor effect and a different interpretation of the approach. The binding approach also explains a good portion of the results, but a new component needs to be added. This, in combination with the fact that the dual-processing approach is more specific and applicable to other areas than just memory conjunction errors, suggests that the dual-processing approach is more promising.

In a future study, it would be interesting to apply a process dissociation procedure (Jacoby, 1991) and then more precisely calculate the quantities of familiarity and recollection. This procedure was excluded in the present study since some of the participants with learning disability could not fully comprehend the exclusion instructions, but more effort can be put into developing a way to explain this concept and a method of response that is adapted to individuals with learning disability.

Generalization

The results for the control group for drawings have the same general pattern as the results in the study by Kroll et al. (1996) (see Table 2). This is important since it validates the fact that this study has examined the same phenomenon. The learning disability group has a similar pattern, but there are also some differences worth noticing. The learning disability group showed more hits and fewer errors of all types than most of the other groups. This implies that their performance could not be attributed to a different judgment criterion only, but rather represents a genuinely lower performance. Furthermore, there are small differences between all groups for all picture recognition types, except for the conjunction stimuli. Here, the results for the different disability groups differ substantially from the results for the groups without disability. This implies that conjunction stimuli could have the potential of being used in assessing important aspects of binding problems in persons with learning disability as well as in other disabling conditions. Further, comparative research is needed to pinpoint the exact nature of memory conjunction errors in different populations.

Summary

To summarize, this study has compared two theoretical approaches to memory conjunction errors. The dual-processing approach was considered to be more promising, but some of the results were not consistent with the approach. However, these results could be explained in terms of a floor effect and a changed interpretation of the approach. The learning disability group made more errors than the control group and scored at a lower level for adjusted hits, but the group differences were of different magnitudes for the different recognition types, which indicate that qualitatively different memory processes are involved for the two groups. In particular, the adjusted error rates for conjunctions are sensitive to group belonging. This result was seen in the present study, and holds true in a comparative sense for studies of other special populations as well. Finally, nonverbal intelligence is not related to performance within the learning disability group, which means that it does not change the pattern of the results.

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