Social Binding:

Processing of Social Interactions in Visual Search, Working Memory and Longer-Term Memory.

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Abstract

The binding of features into perceptual wholes is a well-established phenomenon, which has previously only been studied in the context of early vision and low-level features, such as color or proximity. This thesis investigates the hypothesis that a similar binding process, based on higher level information, could bind people into interacting groups, facilitating faster processing and enhanced memory of social situations. To investigate this possibility, a series of different experimental approaches explores grouping effects in displays involving interacting people. Experiments 1 & 2 use a visual search task and demonstrate more rapid processing for interacting (versus non-interacting) pairs in an odd-quadrant paradigm. Experiments 3 & 4, using a spatial judgment task, show that interacting individuals are remembered as physically closer than non-interacting individuals while retrieval times are decreased for interacting pairs. Experiments 5, 6 & 7 show that memory retention of group-relevant and irrelevant features is enhanced when recalling interacting partners in a surprise memory task. But such retrieval is disrupted when features are misattributed between interacting partners. Finally, Experiments 8, 9 & 10 further investigate the involvement of higher level cognitive processes in these effects. The observed results are consistent with the social binding hypothesis, and alternative explanations based on low level perceptual features and attentional cueing effects are ruled out. This thesis concludes that automatic mid-level grouping processes bind individuals into groups on the basis of their perceived interaction. Such Social Binding could provide the basis for more sophisticated social processing. Identifying the automatic encoding of social interactions in visual search, distortions of spatial working memory, and facilitated retrieval of object properties from longer-term memory, opens new approaches to studying social cognition with possible practical applications.

Table of Contents

Abstract **2**
Table of Contents **3**
Acknowledgments **4**
Author's Declaration **5**
Chapter 1: Introduction **6**
Aims and Scope of this Thesis 7
Visual Search 11
Spatial Judgments 12
Visual Memory 15
Design Decisions and Statistical Assumptions 16
Statistical Power and Replication 16
Response Time Measures 17
Overview of Experimental Chapters 18
Chapter 2: Social Binding in Visual Search **21**
Experiment 1: Symmetric Interactions 22
Experiment 2: Asymmetric Interactions 31
Chapter 2 - Combined and Further Analysis 36
Chapter 2 - General Discussion 38
Chapter 3: Social Binding in Spatial Working Memory **41**
Experiment 3a: Distance Judgments of Interacting Partners 42
Experiment 3b: Row-Scrambled Controls 54
Experiment 4: Same-Direction Controls 60
Chapter 3 - General Discussion 69
Chapter 4: Social Binding in longer-term Visual memory **71**
Experiment 5: Memory for Pair Membership 74
Experiment 6: Memory for Orientation and Color 81
Experiment 7: Memory for Head-Body Combinations 94
Chapter 4 - General Discussion 103
Chapter 5: Boundaries and Future Research Areas **106**
Experiment 8a: Human-Animal Interactions I 110
Experiment 8b: Human-Animal Interactions II 117
Experiment 9a: Background Knowledge of Interaction Partners I 123
Experiment 9b: Background Knowledge of Interaction Partners II 128
Experiment 10a: Human-Like CGI Avatars I 133
Experiment 10b: Human-Like CGI Avatars II 139
Chapter 5 - General Discussion 143
Chapter 6: General Discussion **147**
Summary 148
Social Binding beyond Binary Interactions 150
Social Binding in Context of Non-Social Binding Processes 153
Social Binding in Context of the Current Literature 154
Final Comments 155
Appendix A - Results Tables **156**
Appendix B - Human Stimuli (Chapter 4) **161**
References **166**

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Author's Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Tim Vestner

Chapter 1:

Introduction

Aim and Scope of this Thesis

The processing of current and potential actions and interactions between other people is crucial for successfully navigating the rich and complex social world humans face every day. It has been argued convincingly (e.g., Xiao, Coppin & Van Bavel, 2016) that the capacity to automatically extract key social information by simplifications, abstractions and a priori assumptions, plays an important role in facilitating such processes; however the relevant cognitive mechanisms are, as yet, poorly understood. In low-level perception, one well-established form of simplification takes place in the binding of features into perceptual wholes, known from perceptual binding and the gestalt illusions (e.g., Coren & Girgus, 1980). This thesis investigates whether analogous effects occur at later stages of processing so that, just as visual elements are bound into perceptual wholes, people are bound into social wholes - an idea that will be referred to throughout this thesis as Social Binding and is illustrated in Figure 1.1.

The benefits of such a mechanism are clear: when observing groups of people, observers compute basic social interactions between them rapidly and automatically as an initial perceptual framework for further processing. This becomes clear when one considers entering a social situation containing a gathering of people, such as a party or reception as shown in Figure 1.1 (top). One form of initial grouping could be in terms of the gestalt principle of proximity (Figure 1.1, middle). However, Social Binding proposes that rapid and automatic computations of basic social interactions would provide the framework for subsequent social analysis where attention is more closely focussed on individuals of particular interest. Thus, such a first-pass analysis might initially identify those currently communicating with one another (see Figure 1, bottom), and provide the starting point for more subtle encoding, as status, deception, competition, kinship and intimacy between these observed people (Costanzo & Archer, 1989). This group-based rather than individual-based way of analysing a social scene would not only be faster but might also be expected to benefit visual working memory (Peterson & Berryhill, 2013) in the same way that grouping numbers improves the immediate memory span for series of digits (Severin & Rigby, 1963).

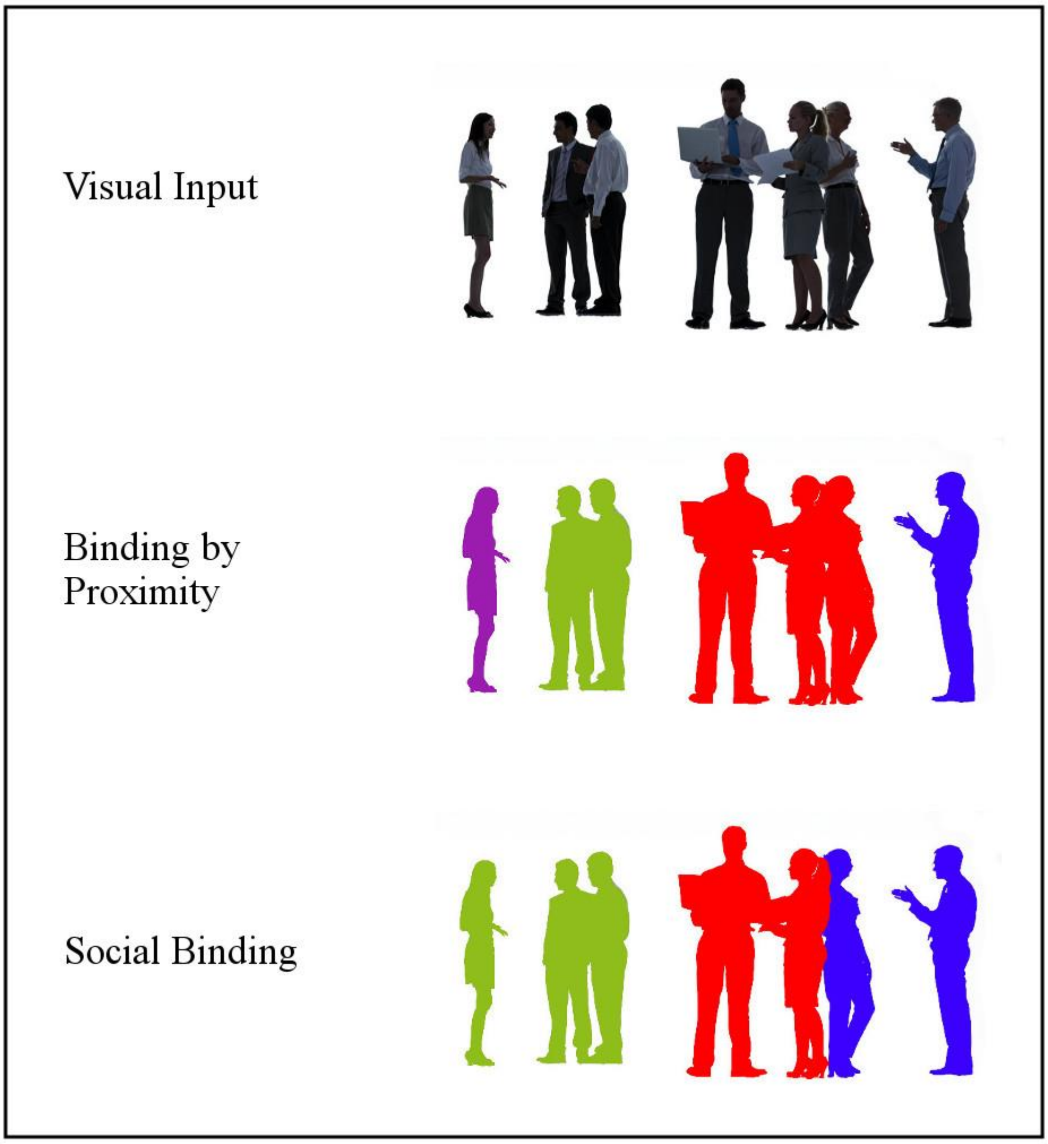


Figure 1.1. Representation of the central hypothesis. When viewing complex displays of interacting people (top), it is possible that the visual input is simplified according to known low-level gestalt principles, such as proximity (middle), in order to facilitate fast processing. This thesis proposes that higher level principles - the evaluation of social interactions - are used instead to bind individuals into groups (bottom).

Social groups can vary wildly on a multitude of dimensions, such as group size, individual characteristics of members, as well as quality and intensity of interaction. No single PhD research programme could hope to provide a comprehensive account of all these factors. Therefore this thesis aims to undertake the initial research to establish whether or not any hypothesised effects consistent with Social Binding are present at all. To this end, the primary focus will be on developing simple displays analysing the processing of interacting with non-interacting dyads throughout various information processing stages from visual search to retrieval from memory. Following this, chapter 5 will provide an outlook into the future of this research by extending the scope slightly to more subtle differences in interactions as well as to non-human "social" stimuli such as avatars.

Indicators for Social Binding from the social-cognitive literature will also be discussed. Predominantly, evidence for top-down effects of social factors on low-level perception will be considered. Processes that, importantly, most previous studies have only investigated from an egocentric perspective. That is, the encoding is within an egocentric frame where the interaction of the perceiver and another individual is the basic unit of analysis, such as during joint action, negotiation, or courtship. For example, perceptual and visual working memory processes such as distance judgements are influenced by such egocentric factors as whether the viewed person is the same or different race to the observer (in- vs. out-group contrasts), or whether the participant observing other individuals has been primed to be socially excluded (Knowles, Green & Weidel, 2013; Xiao et al., 2016, for a review). However, the main concern here is to investigate the automatic and task-irrelevant processing of (potential) social interactions in an allocentric frame, where the relationships between other people are encoded even when they are unrelated to the perceiver. Evidence for such an analysis of interactions that occur independently of the observer would provide a baseline for subsequent research into the cognitive ability to quickly assess human interactions, which factors influence it, and how it might be distorted and disrupted. The aim of this work is to provide an initial theoretical framework for such investigations.

This thesis will therefore explore whether such allocentric computations of social interactions between third-parties take place even when not explicitly required. That is, where social interaction is not directed towards the perceiver, as they remain a third-party neutral observer, and where the status of the social interaction is irrelevant to the participant's task demands. Using previous research into gestalt grouping as a framework, socially interacting and non-interacting groups will be presented in a variety of experimental designs to test for differences in performance along the different visual processing stages. These effects can be categorised into (1) very short-term visual search benefits while viewing a display, (2) short-term working memory effects measured over seconds where spatial distortions are detected and (3) longer-term visual memory benefits. Detecting effects consistent with Social Binding throughout these stages of processing would suggest a fundamental importance of this form of computation for human behaviour.

The following sections will briefly review evidence for each effect category in terms of the perception of low-level visual gestalts and egocentric (i.e., self-other) social interactions. In each case an analogous prediction will be formulated for the perception and memory of allocentric (i.e., third party) interactions, which will be investigated in this series of studies.

Visual Search

Previous work has demonstrated that elements bound together into a gestalt are detected faster and processed more quickly in visual search tasks (e.g., Coren & Girgus, 1980). This effect has been shown for both feature search (Hawkins, Houpt, Eidels & Townsend, 2016) as well as conjunction search (Hegdé & Felleman, 1999) with feature search showing response time advantages of bound figures over single elements whereas conjunction searches show advantages of bound figures compared to unbound figures.

Other work has shown that egocentric social identities can also influence visual search performance. For example, priming racial identity influenced search for black vs white faces in Black-White biracial individuals, such that priming their black identity, for example, facilitated detection of black faces (Chiao, Kenser, Nakayama & Ambady, 2010). Similarly, in multiple face displays attention can be preferentially oriented to faces within an individual's social in-group (Brosch & Van Bavel, 2012).

More recent research to emerge during the period of this thesis (Papeo, Stein and Soto-Faraco, 2017) found that when asking participants to categorise objects into 'bodies' or 'objects', categorisation speed and accuracy were improved significantly when the target object was a seemingly interacting pair, compared to non-facing pairs or objects. This advantage of processing facing dyads was impaired when stimuli were inverted. These results are consistent with the theory of Social Binding in that the facing pair might have formed a socially bound group and been therefore located and processed faster. The preferred processing of social events is also indicated by the very recent findings of Morrisey, Reed, McIntosh and Rutherford (2018), who found that actions performed by one individual towards another are processed preferentially over those actions that have an inanimate target. This automatic cueing of social scenes was not present in observers with autism spectrum conditions. Social Binding could provide a unified explanation here as well, in that if both actors are perceived to have agency, they are bound into a singular event.

This thesis will examine social binding processes when there is no egocentric commitment to the searched-for items. That is, there is passive viewing of neutral displays that are not related to the observer and the observer's state, such as inclusion or exclusion from social groups, is not manipulated. To this end, the experiments in Chapter 2 compare search for paired individuals who are either looking towards each other or looking away from each other. The prediction is that the social interaction in the looking-towards condition will be automatically computed and hence these displays will be detected more fluently. If such facilitated search effects are driven by social interactions, then they will not be observed with inanimate objects with a front facing property, and not be solely determined by low-level perceptual properties such as symmetry.

Spatial Judgments

Perceptual binding is known to influence spatial judgments in that bound elements are remembered as being closer together than non-bound elements (e.g., Coren & Girgus, 1980). It might seem surprising to consider the possibility of top-down influences of abstract concepts on vision and visual memory, but current literature examining egocentric frames of reference supports the notion of high-level social influences on perception and spatial judgments (Xiao et al, 2016). Egocentric here refers to the perception of situations that involve the observer, i.e. direct interaction with an object or the perception of the distance from the observer to a stimulus. Allocentric, on the other hand, refers to the observation of objects unrelated to oneself or the perception of another's interaction with a stimulus. Naturally, egocentric and allocentric perception involve different cognitive processes. This is shown, for example, in findings that egocentric distance judgments are faster and more accurate than allocentric judgments (Iachini & Ruggiero, 2006). Similarly, future actions are predicted more accurately when observed from an egocentric rather than allocentric viewpoint (e.g., Brattan, Baker & Tipper, 2015). However, these processes are also closely connected to each other with observers spontaneously taking another person's perspective when asked to describe situations in which the other but not the observer was involved (e.g. Tversky & Hard, 2009). Observation of actions activates the observer's own motor representations of those actions (e.g. Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2004), facilitating simulation, recognition and understanding of those actions (Knoblich & Sebanz, 2006) as well as coordination of one's own actions with those of a partner (Sebanz, Knoblich, Prinz & Wascher, 2006; Sebanz, Bekkering & Knoblich, 2006).

One particular social behaviour that has been mapped onto egocentric perception distortion is the tendency of individuals to maintain a larger distance to other people's front than to their back (Hayduk, 1981): Jung, Takahashi, Watanabe, de la Rosa, Butz, Bülthoff and Meilinger (2016) have shown that this egocentric distance judgment between self and other extends from immediate behaviour and is reflected in subsequent memory. For example, participants remembered decreased distances to virtual avatars that were facing them as compared to those that were turning their backs. Jung et al.'s (2016) study leaves open whether these spatial distortions are caused by high level social or low level visual processing; a common question which the current study aims to examine more closely. Jung et al.'s (2016) manipulations of towards or away facing displays provide a convenient and easy way to manipulate the perceived interaction and therefore grouping of individuals. Hence, Chapter 3 examines whether such distortions of spatial memory can also be detected and employed to study allocentric third-person frames when a passive observer encounters interactions between other people. The hypothesis here is that when observing two individuals interacting, when they are looking towards each other, they will subsequently be recalled a few seconds later as being physically closer together than if they had been looking away from each other.

The distortion of spatial perception and memory is also, of course, influenced by properties of stimuli that evoke emotional reactions. That is, threatening and fear evoking stimuli are perceived and recalled as further away when the observer is able to move away from them, but are recalled as closer when this is not an option and confrontation is necessary (Harber, Yeung & Iacovelli, 2011; Cole, Balcetis & Dunning, 2012). Similarly, threatening interaction partners are perceived as closer both when directly observed (Cesario, Plaks, Hagiwara, Navarrete & Higgins, 2010) and also when visualised (Xiao & Van Bavel, 2012). A review is provided by Balcetis (2015) and further discussed in Chapter 5.

When considering spatial distortions on the basis of socio-cognitive processes, it is necessary to consider recent and as yet unresolved debates regarding the existence of social top-down effects on visual perception (e.g. Balcetis, 2015; Firestone & Scholl, 2015; Schnall, 2017; Xiao, et al., 2016). While the hypothesised results are similar to these findings, it is important to stress that Social Binding would interpret spatial distortion effects in terms of reconstructive memory effects and visual representations held in the episodic buffer of visual working memory (Baddeley, Allen & Hitch, 2011), not necessarily perception itself. The research undertaken here is therefore outside the scope of this debate and cannot lend substantial support to either position.

Visual Memory

Chapter 4 examines the encoding and retrieval of allocentric social interactions over longer periods of minutes in surprise memory tasks that participants were not expecting. That is, even though participants were never instructed to attend to individual identities or the social interactions between pairs of individuals, these are automatically computed. This leads to a grouped representation of the dyad in the episodic buffer (Baddeley et al., 2011), which in turn is stored as a single chunk into memory (e.g. Sargent, Dopkins, Philbeck & Chichka, 2010). Literature investigating elements that are bound into figures according to low-level features found that such elements are bound into a single engram and retrieval of one is facilitated by the presence of the other (e.g., Woodman, Vecera & Luck, 2003; Horner & Burgess, 2013; Wallace, West, Ware & Dansereau, 1998). It is therefore hypothesised here that, due to social grouping processes, individuals implied to be socially interacting form coherent groups, they are encoded together and retrieval is facilitated. Therefore memory accuracy for common as well as individual features of persons involved in social interactions will be enhanced.

However, a special case and secondary hypothesis is presented by findings regarding perceptual averaging of grouped elements (Alvarez, 2011; Im & Chong, 2014). When elements are stored as part of a group according to gestalt principles, the representation and subsequent retrieval is altered in that features are remembered to be more closely aligned to the mean of the remembered group (Corbett & Oriet, 2011; Corbett, 2016). Therefore, in cases where features of an individual might be averaged or confused with features of their partner, it is predicted that observers are less accurate in remembering these features for individuals that are part of a grouped dyad. The experiments in Chapter 4 will investigate both these predictions further.

Design Decisions and Statistical Assumptions

Statistical Power and Replication

Before starting any experiments or analyses it was necessary to establish the statistical assumptions that shall govern all designs and analyses throughout this thesis. Firstly, it is necessary to determine the desired number of participants: As this thesis investigates effects that have previously not been studied, a medium effect size (Cohen's d = 0.5 / Cohen's f = 0.25) and a power of 75% will be assumed. Following a power analysis in R, these assumptions yield target participant numbers of (rounded up to the nearest 10) 30 participants for the planned paired t-tests; 40 participants for the planned one-way four-level repeated measures ANOVA; and 60 participants (30 per between subjects condition) for any 2x2 mixed ANOVA. No single participant took part in more than one experiment throughout this thesis.

In the interest of consistency and comparability, all tests throughout this thesis will use these targets as long as the expected effect size is larger than the one assumed here (i.e. as long as any specifically calculated requirements would be less than the number of participants calculated here). Importantly, in addition to these considerations all novel findings will be replicated and extended at least once. All recorded data can be found under the link https://osf.io/4v8zw/. More exhaustive descriptives can also be found there as well as in Appendix A.

Response Time Measures

Various experiments will differentiate between reaction times and response times. Reaction times will refer to those designs that explicitly require the participant to respond as quickly as possible. This is typically the case if the reaction time is the central measure of the experiment. Response times shall refer to those experiments where a different measure was the main variable of interest and response times were collected only incidentally, i.e. participants were not asked to respond as quickly as possible.

As all experimental designs include response time measures of either kind, a framework for their recording and analysis on the basis of Whelan (2008) will be used throughout this work: Trials with too short a response time are typically not genuine but due to fast guessing or accidental responses (see also Luce, 1991). Therefore, trials will be discarded if their response time is shorter than 200ms for experiments that involve button press / release responses and 500ms for experiments that involve arm movements. As response times are typically positively skewed, a decision on processing of long response times and outliers also has to be made. Inverse or logarithmic transformations would be possible but reduces power more than cutoff points while having comparable Type I error rates (see also Ratcliff, 1993). As outliers are expected - especially in those designs that do not require participants to react as fast as possible - and any Social Binding Effects would be expected in the fast to intermediate response times, the best procedure according to Ratcliff (1993) in terms of highest power without increasing Type 1 error rates is to establish absolute cutoffs that are low enough to remove outliers but high enough not to exclude real data. Cutoffs for all reaction time measures have therefore been set to 3000ms while those for response time measures have been set to 5000ms. Long term memory recall did not use cutoffs as participants were allowed to take as much time as they needed. These high cutoffs will still leave most response time data slightly skewed but parametric tests are robust to small skew at the targeted sample sizes (see Piovesana & Senior, 2016), especially of course in within-subjects designs, which are used in this thesis wherever possible.

All experiments were approved by the ethics committee of the Department of Psychology at the University of York. All participants gave their informed consent prior to starting any experiment.

Overview of Experimental Chapters

As stated earlier, the initial investigation into any Social Binding effects requires the use of a simple stimulus in the form of a dyad that can be manipulated to be visibly interacting in an unambiguous way. Both the studies by Papeo et al. (2017) as well as Jung et al. (2016) indicate that interaction between two people can be most easily manipulated by arranging the figures into facing and non-facing pairs. This comparison will be the main focus of all experimental chapters, with the exception of control stimuli, until Chapter 5, which will consider additional stimuli and manipulations.

Chapter 2 will present two experiments using an odd quadrant task (e.g. Pomerantz, Sager & Stoever, 1977; Hawkins et al., 2016) to investigate for any response time advantages in visual search. Experiment 1 will compare the search for Towards and Away oriented pairs and contrast this with a control condition in the form of Towards and Away facing inverted pairs (see Yin, 1969; Reed, Stone, Bozova & Tanaka, 2003). To replicate the findings of Experiment 1 and account for possible low level confounds, Experiment 2 will repeat this paradigm with less symmetrical pairs in the experimental condition and objects in the control condition.

Chapter 3 will focus on short-term working memory and will investigate response times and accuracy in a novel spatial judgment task. Experiment 3a will present participants with Towards or Away oriented pairs and objects in the experimental and control condition respectively. After a short exposure time they will see one of the people/objects again and will be asked to place the corresponding partner in space relative to the visible one. Experiment 3b will offer an additional control condition in the form of row-scrambled versions of the same pairs presented in Experiment 3a. Experiment 4 then will further control for a variety of alternative accounts (e.g., attention, forward modelling) by using the same design to present pairs of people in not only the Towards and Away conditions, but also same-facing Left and Right conditions.

Chapter 4 will investigate potential effects of Social Binding on longer-term visual memory. Using only human stimuli, the same spatial task as in chapter 3 will be used to facilitate automatic encoding of the presented pairs into memory. All memory tasks that follow this encoding will be surprise memory tasks. In Experiment 5 the memory task is aimed at establishing whether pairs are truly bound together into memory by investigating whether members of interacting pairs could be more accurately and quickly identified as belonging to the same dyad than those that were members of non-interacting pairs. Experiment 6 will then establish whether memory benefits of Social Binding are only present when remembering group-relevant features or also when remembering group irrelevant features. Finally, Experiment 7 will then investigate the presence of other memory effects such as perceptual averaging resulting from Social Binding.

Chapter 5 will attempt to lay the foundations for future research by extending the previous findings to different manipulations and stimulus categories. Experiment 8 will investigate binding effects on the basis of threatening or non-threatening interactions. Similarly, Experiment 9 will explore whether abstract knowledge of a pair of individuals can facilitate Social Binding regardless of their current physical orientation. Finally, Experiment 10 will use computer-generated human-like stimuli to probe whether Social Binding can be extended to representations rather than reproductions of human bodies.

Chapter 2:

Social Binding in Visual Search

Experiment 1: Symmetric Interactions

Humans inhabit highly complex worlds. They have evolved extremely efficient perception-action systems to encode information from the world to enable behaviours that support survival. Because the speed and accuracy of such perception-action processing is crucial, much of these processes take place automatically. For example, merely viewing an object that affords an action, automatically activates the appropriate action. However, a problem with such an efficient rapid and automatic perception-action system is the guidance of behaviour to the correct object at exactly the right moment in time. This coordination of action requires excitatory and inhibitory processes in attention systems (e.g., Houghton & Tipper, 1996).

An example is the problem of grasping a glass from a table containing other glasses that evoke similar competing actions (e.g., Tipper, Lortie & Bayliss, 1992). What is required is an efficient search process to identify the correct object from the cluttered scene to enable the appropriate action. Therefore, such an initial selection process when searching for a specific target object is a fundamental first step to achieving behavioural goals. In the case of the social binding issue investigated here, initial rapid analysis of complex scenes to identify important social interactions might be predicted as a first stage for further consideration and decisions concerning the observed social situation.

Therefore the first experiment tested for reaction time differences in visual search depending on whether a dyad of individuals is implied to be interacting. This interaction was manipulated using the body orientation of the individuals: Towards-oriented individuals were looking at each other, thereby implying the potential for interaction while Away-oriented individuals were not interacting. Any grouping processes resulting from social interaction would predict a faster processing of interacting individuals (Wagemans et al., 2012) and therefore faster detection of interacting pairs.

To investigate this, the odd-quadrant task introduced by Pomerantz et al. (1977) was adapted for the investigation of socially interacting stimuli. It is important to note that this task is usually used to investigate reaction time advantages of bound elements as compared to single elements (e.g. Hawkins et al., 2016), thereby showing pre-attentive, “attention-capturing” effects. However, contrary to most classic gestalt binding effects, no pre-attentive effect is expected here due to the fact that whether two individuals are interacting cannot be determined by only one stimulus feature but rather a conjunction of features. Therefore, Social Binding would be expected to produce response time benefits in serial processing during conjunction search. Consequently, the experimental paradigm here does not compare the search for two bound elements with searching for one single element but rather searching for two grouped individuals with searching for two non-grouped individuals.

A control condition was also added where the individuals were inverted (see Figure 1). Following on from the face and body perception literature (e.g., Yin, 1969; Reed et al., 2003) it was assumed that inverted images, although possessing the same physical features as upright images would not be processed as socially interacting. This assumption is supported by the recent demonstration of the “Two-body inversion effect” (Papeo, et al., 2017), which evidences that stimuli are more readily processed as human when in an upright rather than inverted configuration. Hence, such a control condition provides an initial examination of the role of low-level perceptual properties such as symmetry in any found effects. This is especially relevant as it has previously been shown (Bayliss & Tipper, 2006) that gaze cueing effects are present even when head orientation is manipulated away from the normal upright orientation. Effects resulting from gaze cueing are therefore accounted for by the inclusion of an inverted control condition as well.

Methods

Participants

60 participants (6 male, 54 female) were recruited from the student population of the University of York and reimbursed with either course credit or a payment of £3. Half of those participants (4 male, 26 female) were randomly assigned to the upright experimental condition with the other 30 (2 male, 28 female) assigned to the inverted control condition.

Materials

Photographs of two same-sex models were sourced from the Adobe Stock Service. Both featured a side-view of a male model in an upright standing position, hands at their side. The images were normed to a height of 350 pixels and mirror images for each model were generated on both axes so the to-be-localised target stimuli could be arranged either facing each other (Towards condition) or with their backs turned (Away condition). The distractor stimuli presented in the other 3 quadrants were the same two individuals facing in the same direction (either all facing to the left or to the right, randomised). In the inverted control condition all the displays were the same, except that the stimuli were inverted. See Figure 2.1 for an example of target stimulus pictures and Figure 2.2 for a typical search array. A simple image of a black cross on a white background served to divide the screen into four equal sections. The experiment itself was created using Unity3D (Version 5.2.1f1) and displayed on a ProLite T2735MSC 27-inch touchscreen at a resolution of 1920x1080.

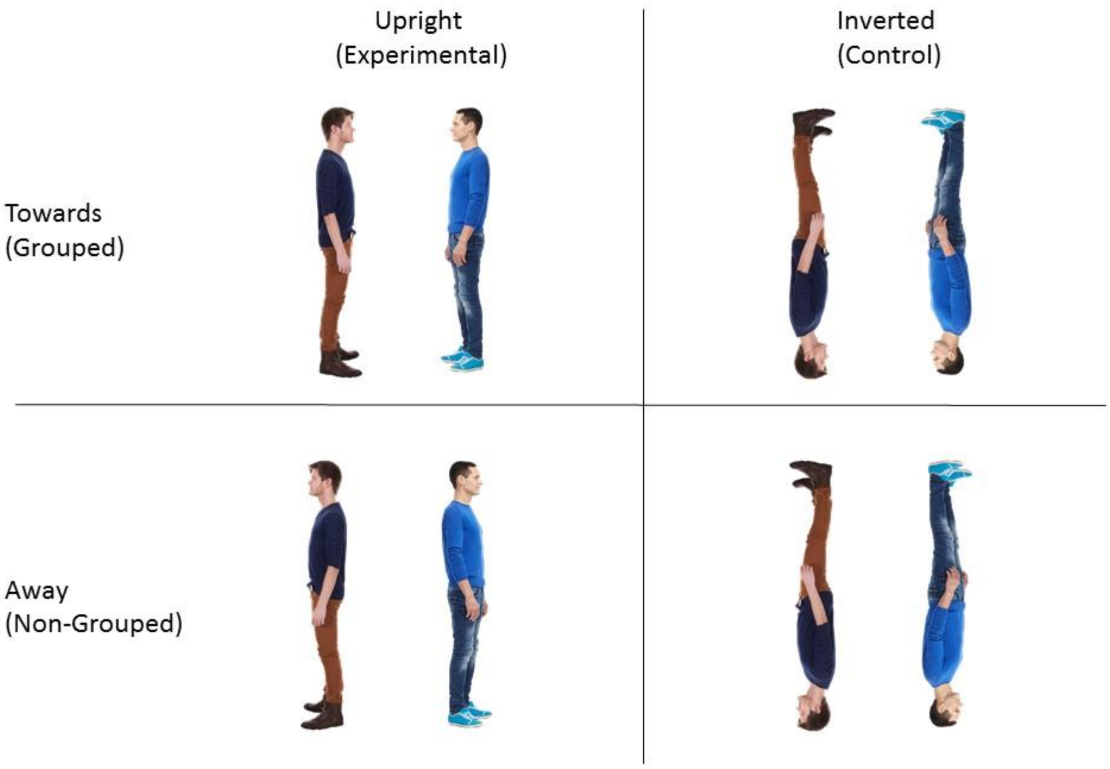


Figure 2.1. Upright (experimental) and Inverted (control) target stimuli in both Towards and Away orientation.

Figure 2.2. An example of the search array presented to the participants. The target is an example of the Toward condition and located in the upper left quadrant.

Design

A mixed 2x2 ANOVA was used, analysing the effect of orientation of stimuli (Towards or Away; within subjects) and type of stimuli (Upright experimental, Inverted control; between subjects) on response times in a visual search task. Reaction times were measured starting from the appearance of the stimuli caused by the participant holding down a key; and until the participant let go of the key at the start of the pointing response, which caused the stimuli to disappear.

Procedure

Participants were invited into the experimental room individually. They were handed an information sheet containing a rough outline of the experiment as well as informing them about their right to withdraw at any point during the experiment. After they consented, they received both verbal as well as written instructions and completed four practice trials under the supervision of the experimenter.

The experiment was divided into two blocks, with the target of the visual search being either the Towards orientation in one block and the Away orientation in the other. Blocks started with a display of the target pair to familiarise the participant with their target. Participants were able to take a break in between blocks. Order of blocks was counterbalanced.

Each trial started with a cross that divided the screen in 4 equal sections. Whenever ready, participants held down the spacebar, which caused four pairs of people to appear on screen - one per quadrant. One of these pairs was in either consistently Towards or Away orientation (Target) within a block of trials while the individuals in all other pairs were looking in the same direction as their partners, either left or rightwards (Distractors). Location of the Target among the four sections as well as facing direction of the distractors were randomised.

Participants were asked to find the Target pair as quickly as possible, by releasing the spacebar and touching the section of the screen that contained the target. Stimuli disappeared when participants released the spacebar, so the decision had to be made before starting the movement. For a visualisation of the procedure, see Figure 2.3. Response time was measured from pushing down to letting go of spacebar. This eliminated any confounds affecting the time it took participants to reach the target, such as target location or whether the target area was attended by surrounding stimuli.

Participants completed 40 trials in each block. Overall the experiment took less than 15 minutes. Error rates were below 6% for all participants (<4% overall).

Incorrect trials have been excluded from all further analyses. Additionally, all trials with reaction times shorter than 200ms and longer than 3000ms were excluded (<2% of trials).

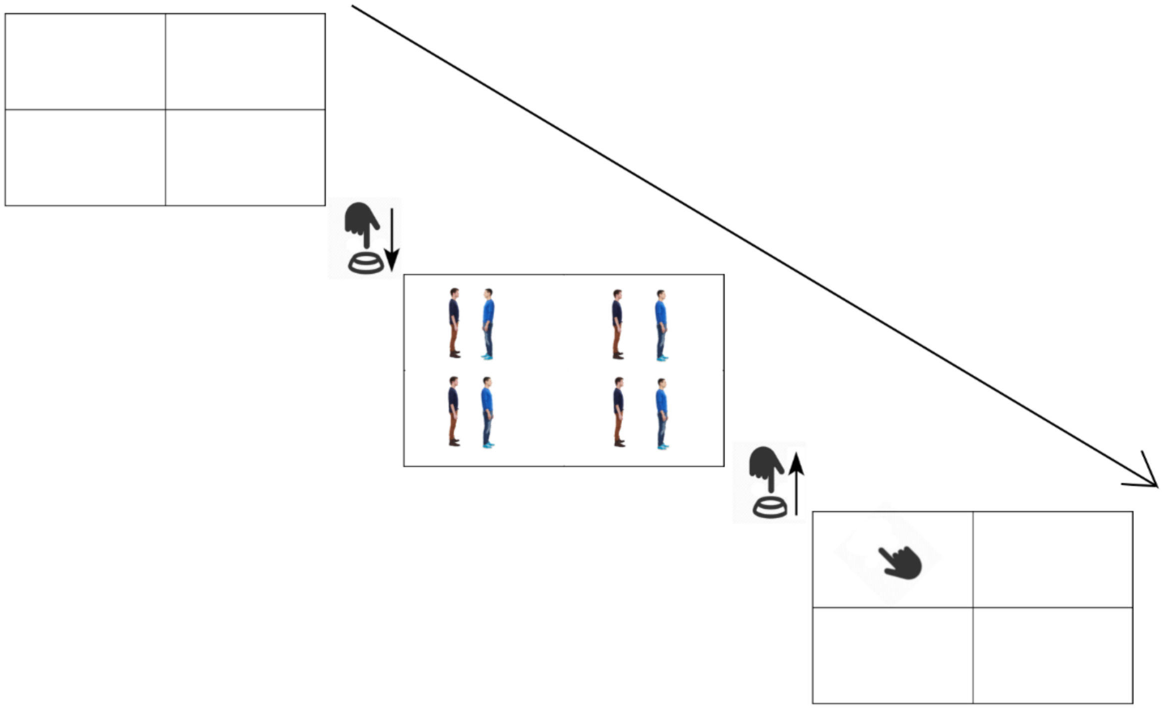


Figure 2.3: Experimental procedure involving an upright trial with the towards facing target in the top left.

Results

A mixed 2x2 design showed a significant effect for Towards/Away orientation of target stimuli ($F(1,58)=13.77$, $p<.001$, $\eta_p^2=.192$), confirming the prediction that target detection is faster for Towards-oriented individuals. There was also a main effect of Upright/Inverted target orientation $F(1,58)=10.52$, $p=.002$, $\eta_p^2=.154$) where search speed was slower for Inverted individuals, as predicted. The interaction between both variables was significant ($F(1,58)=6.25$, $p=.015$, $\eta_p^2=.097$). See left panel of Figure 2.4 for mean reaction times.

Post-hoc tests based on this interaction revealed that Towards-oriented pairs were found significantly (Bonferroni corrected) more quickly than Away-oriented stimuli in the experimental (Upright) condition ($t(29)=3.45$, $p=.002$, $d=0.63$) but not in the (Inverted) control condition ($t(29)=1.39$, $p=.174$).

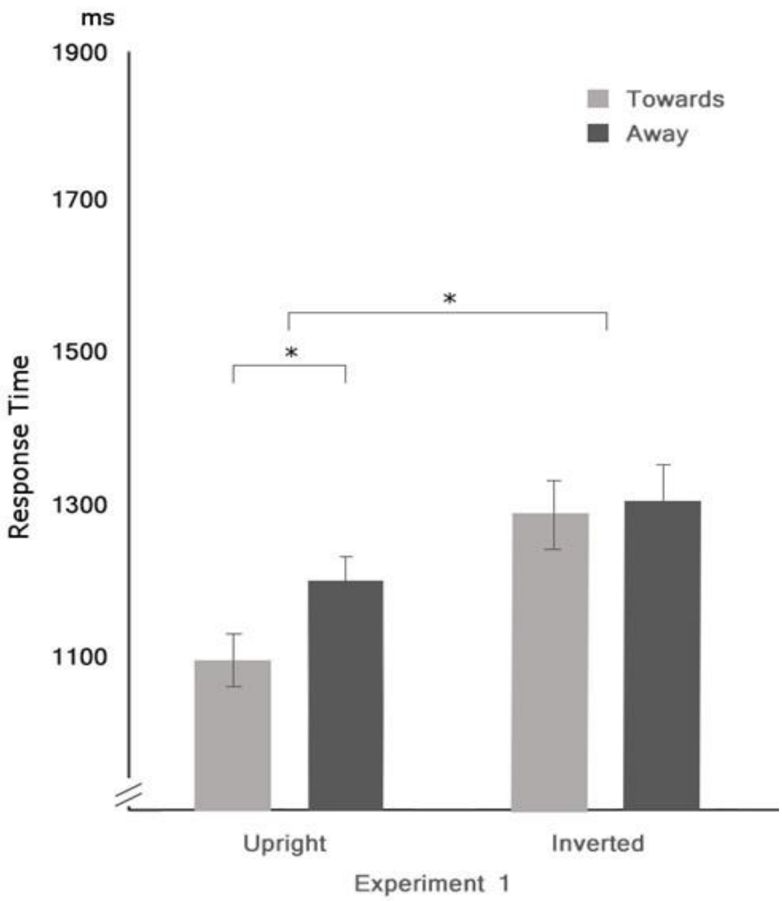


Figure 2.4. Mean reaction times for grouped and non-grouped stimuli for Experiment 1. Error bars represent standard error. *p<.05 **p<.001

Discussion

Searching for pairs of people who are oriented towards one another leads to a significantly faster detection compared to searching for those in the Away orientation, but only when the people were viewed in a normal upright orientation. This supports the hypothesis that the computation of social interactions is of importance and given privileged access to later processes. This social interaction effect was not detected when the individuals were inverted, confirming the results of Papeo et al. (2017) and ruling out explanations based on low-level perceptual features.

Because this is the first demonstration that there appears to be preferential encoding of some kinds of social allocentric interactions during visual search, it is necessary to replicate and extend the findings to new situations. The lack of effect in the Inverted control condition would seem to support the idea that low-level explanations such as symmetry producing Kanizsa-like effects of closure and good continuation (e.g., Coren & Girgus, 1980) is an unlikely explanation of the results. However, to confirm this the following study examines Towards and Away social interactions when there is no symmetry.

Experiment 2: Asymmetric Interactions

A second visual search experiment is valuable not just to replicate the findings of Experiment 1 and further investigate possible confounds, but to also test whether the previous results extend to visually very different social stimuli. The main concern regarding the results of Experiment 1 was the possibility that the symmetry of stimuli might have facilitated gestalt binding due to more classical features, such as good closure or the feature-rich fronts of stimuli mirroring each other in facing dyads. While the body-inversion effect (Reed et al., 2003) seems to have provided a good control condition that is not evaluated to be socially interacting, it is also possible that due to this effect the classification of stimuli into facing and non-facing pairs forced focus onto details rather than processing the stimuli holistically, which has previously been found to disrupt gestalt grouping (e.g. Brosnan, Scott, Fox & Pye, 2004). It is also possible that processing was delayed too long for gestalt binding to provide an advantage to searching for facing pairs. This is of particular concern as the inverted stimuli were processed significantly slower. In both of these cases it would be possible that the difference in orientation in upright dyads resulted from low-level rather than social features and that this would not be ruled out by the inverted control condition.

Therefore, in Experiment 2 experimental stimuli were used that did not possess any symmetry that might lead to classic gestalt binding. Additionally, controls used here were objects (wardrobes) shaped in a way that would allow for gestalt binding according to good continuation or closure, while still allowing for fast processing without the presence of inversion effects. Therefore, if low-level features were the cause of perceptual binding in Experiment 1 then no difference between orientations would be expected in the experimental human stimulus condition while a similar difference to Experiment 1 should be found in the control wardrobe condition. If Social Binding was the cause then the same pattern of results as in Experiment 1 would be expected.

The study further extends the previous findings by implying not just a somewhat neutral interaction through body orientation but also a specific social relationship between partners: To this end, the stimuli pictured an adult man and a child, implying a more salient, potentially emotion-based, parent-child relationship. This difference in social quality rather than just the mere presence of an interaction might lead to stronger effects here than in the previous condition that featured two adult men in a neutral upright posture and neutral stare, in an unknown relationship.

Methods

A further 60 participants were recruited from the same pool as the previous experiment and divided into the person experimental (1 male, 29 females) and wardrobe control (30 females) conditions.

Design and procedure were identical to Experiment 1 but stimuli were replaced with pictures of asymmetric social pairs (experimental) and wardrobes (control). See Figure 2.5 for samples of all stimuli. Error rates were below 5% for all participants. Incorrect trials have been excluded from all further analyses, as have all trials with reaction times below 200ms and above 3000ms (<2.5%).

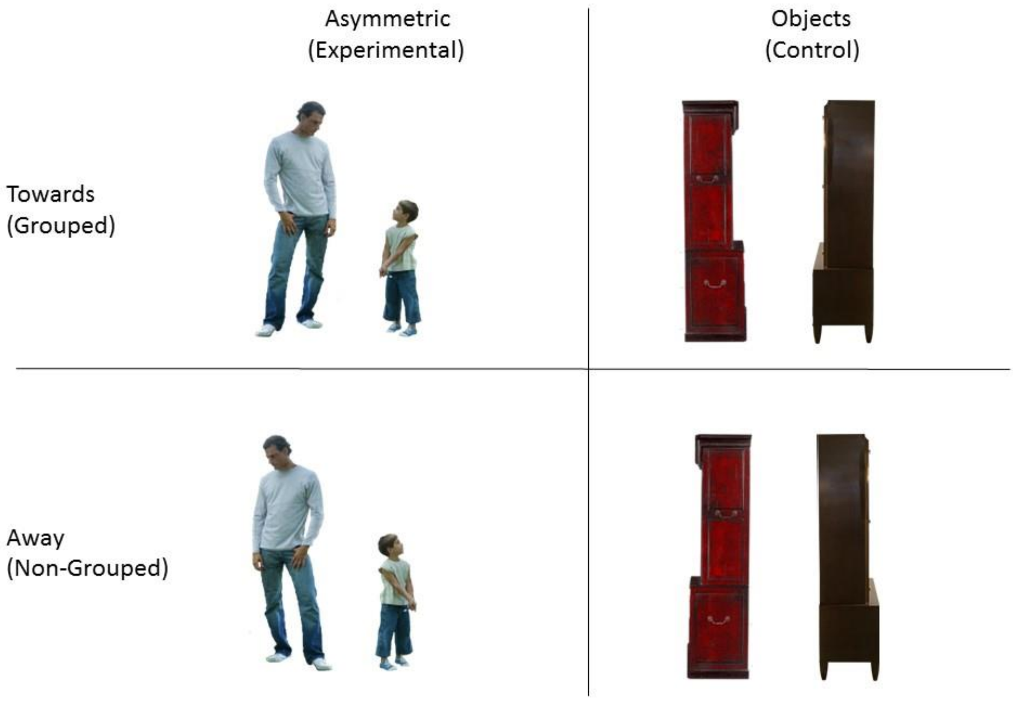


Figure 2.5. Asymmetric pairs (experimental) and Objects (control) in both Towards and Away orientation.

Results

A mixed 2x2 ANOVA showed a significant effect for Towards/Away orientation of stimuli ($F(1,58)=20.99$, $p<.001$, $\eta_p^2=.266$) but no significant main effect of Person/Wardrobe stimuli ($F(1,58)=0.12$, $p=.736$). The interaction between both variables was significant ($F(1,58)=18.65$, $p<.001$, $\eta_p^2=.243$). See right panel of Figure 2.6 for group means and how they compare to the results from Experiment 1.

Post-hoc tests based on this interaction revealed that Towards-oriented pairs were again found significantly more quickly than Away oriented ones in the Person experimental condition ($t(29)=7.40$, $p<.001$, $d=1.33$) but not in the Wardrobe control condition ($t(29)=0.17$, $p=.870$).

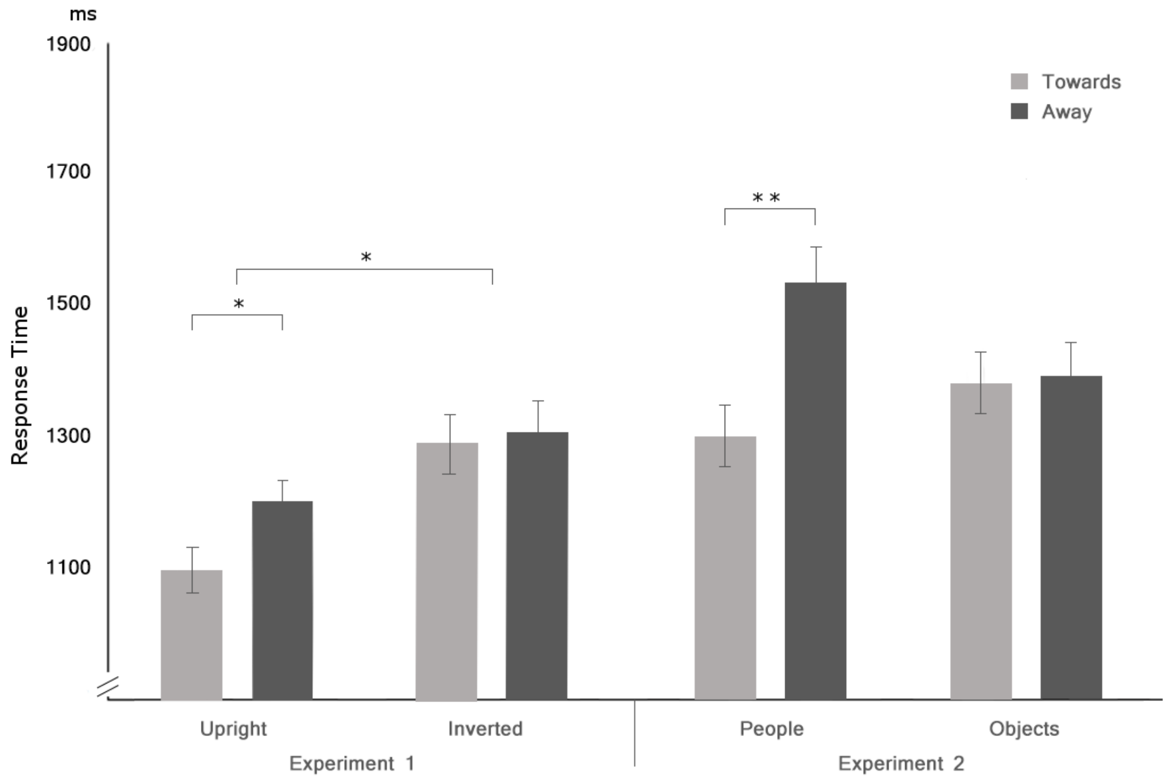


Figure 2.6. Mean reaction times for grouped and non-grouped stimuli for Experiment 1 (left panel) and Experiment 2 (right panel). Error bars represent standard error. *p<.05 **p<.001

Discussion

The same pattern of results from Experiment 1 was found in Experiment 2: While social stimuli show a reaction time advantage in Towards-orientation, there is no difference between Towards and Away orientations in Objects. This extends the previous findings to non-symmetric stimuli and therefore beyond conditions where known gestalt principles potentially apply. The observed difference for orientation in the experimental stimuli was, in fact, larger both in raw magnitude as well as in effect size. Whether this difference between experiments was significant will be analysed in the following section.

The control condition using objects further ruled out low level confounds on the basis of gestalt-binding due to the principle of good closure: As the straight backs and indented fronts of the objects were forming a rectangular figure between them even more clearly than the symmetric experimental stimuli in Experiment 1, any such confound would have led to significant effects in the control condition as well. Furthermore, the control stimuli were processed similarly quickly as the experimental stimuli so slower processing can also not account for the difference in conditions.

Chapter 2 - Combined and Further Analysis

Comparison of Experimental Conditions between Experiments 1 and 2

While it has been shown that the stimuli in both experimental conditions produce significantly different reaction times between their orientations, it is worth comparing the effects between those stimuli. Until now Social Binding has been discussed in terms of a binary phenomenon with two people being either bound or not. However, it is possible that this binding can differ in strength between groups and therefore produce stronger effects. Such an increase in effect sizes could be hypothesised due to the experimental stimuli in Experiment 2 being more obviously interactive, subjectively more expressive and exhibiting a qualitatively stronger relationship: The interaction is more obvious as the man and child in Towards orientation are clearly looking at each other while the same-sized stimuli in Experiment 1 could be interpreted as simply looking ahead and past the partner. Additionally, while the two adult figures do not obviously fit into any category of relationship, the man and child might readily be understood to be in a parent-child relationship - arguably one of the most salient and qualitatively strongest relationships. As the effect size for the difference between orientations is descriptively larger in the social stimuli of Experiment 2, it was investigated here whether this difference is significant.

A mixed 2x2 ANOVA was performed on the human experimental stimuli of both experiments 1 and 2 with Orientation (Towards/Away, within subjects) and Stimulus (Symmetric/Asymmetric, between subjects) as independent variables. Unsurprisingly, there was a highly significant effect of Orientation ($F(1,58)=60.58$, $p<.001$, $\eta_p^2=.511$) and also for Stimulus category ($F(1,58)=22.22$, $p<.001$, $\eta_p^2=.277$). Importantly, the interaction was also significant (F(1,58)=9.24, p=.004, η_p^2=.137), indicating that the Towards vs Away search effect was substantially larger in the Experiment 2 adult-child condition (240ms) than in the adult-adult condition of Experiment 1 (100ms) (see Figure 2.6 as well as Appendix A).

Movement Time analyses for Experiments 1 and 2

In order to investigate whether time to reach for the target is influenced by the target orientation by, for example, participants holding the search display in working memory and letting go before locating the target (Meegan & Tipper, 1998), movement times, i.e. the time from letting go of the key to touching the screen, were analysed. This analysis revealed that pure movement times, starting from the participant letting go of the pressed key to touching the screen, yielded no significant main effects for either Orientation (F(1,58)=1.63, p=.207; F(1,58)=0.17, p=.680) or Stimulus category (F(1,58)=0.45, p=.506; F(1,58)=0.16, p=.690) and no interactions (F(1,58)=0.02, p=.882; F(1,58)=1.54, p=.219). For further information, see Appendix A as well as the supplementary material online.

Chapter 2 - General Discussion

These initial studies have examined the idea that when observing social situations containing a number of other people, interacting dyads receive preferential processing. In particular, even when the social information is not directed towards the viewer, detecting whether other people are interacting is of importance when interpreting the scene. Two visual search experiments have clearly confirmed the predictions of Social Binding and provided the first evidence that facing individuals are inferred to be interacting and socially bound. That is, participants were significantly faster to detect a target stimulus when it was two people oriented towards each other as in a social interaction, than when they were oriented away from each other.

To argue that the search performance was determined by high-level computations of social interactions, it was critical to rule out the lower-level perceptual properties that typically explain grouping and facilitated search, such as symmetry. Such low-level accounts were discounted in three ways: First, when images of people were inverted they contained the same physical properties and gaze direction cues but social processing is disrupted in such situations, similar to face inversion effects. In this situation, social orienting effects were not detected (see also Papeo et al., 2017). Second, and similarly, when inanimate objects with a clear front and back were the search targets, no effects were detected, confirming the effects are associated with animate social stimuli. Third, and finally, the search advantage for social interactions was even detected when asymmetrical stimuli were employed, and when the interaction was between a child and adult.

The preliminary finding of an increase in effect size in Experiment 2, potentially due to a qualitative increase in perceived interaction or relationship, could be interpreted as evidence that Social Binding is not a binary phenomenon that differentiates between interacting and non-interacting stimuli. But instead these binding processes might lead to effects that gradually increase with strength of the interaction or relationship. This question will be investigated more closely in Chapter 5 of this thesis.

As it is the intent of this work to create a foundation for future research into Social Binding, a closer evaluation of the experimental paradigms may prove valuable in the future: The recording of reaction times using a key-holding paradigm has shown to be not statistically different than using a more common time-until-response measure. Nonetheless, recording the dependent variable in this way gives participants the opportunity to start the trials in their own time, reducing fatigue effects, and decreases the noise resulting from arm movements to different screen locations while also eliminating as much as practical the possibility of participants using the time during movement to locate the target (see Meegan & Tipper, 1998). Therefore any future studies should leave this measure unaltered. Using same-facing pairs as distractors also seemed to provide a sufficiently neutral stimulus that doesn’t exhibit binding that would influence the results (see also Experiment 4).

In terms of research questions beyond the evidence for the presence of Social Binding provided here, studies may focus on manipulating the implied interaction as well as investigating individual differences between observers: Preliminary evidence from the comparison between the two experimental stimuli used in this chapter provides tentative support for the quality of relationship influencing the size of the binding effect. This opens up potential research avenues into not just different kinds of interactions (e.g. aggressive, cooperative or romantic) but also different kinds of dyads (e.g. in- and outgroups, person-object interactions or simplified human representations). Going further, this might interact with individual differences in that binding strength of different relationships might be mediated by the observer's own experiences and biases: Outgroups might be less readily seen as interacting if the observer has a strong group-identity associated with one of the groups. Similarly, pairs of women and tools stereotypically used by men (or vice versa) might be less readily bound together by observers with strong gender biases. If true then the presented paradigm could potentially be adapted into a new form of implicit bias test. Other individual differences disconnected from interaction quality might be found in patients with disorders that show a disruption to social perception. Such disruptions to socio-cognitive processing have been shown for example to be associated with both schizophrenia (e.g. Okruszek, Piejka, Wysokiński, Szczepocka & Manera, 2018) and autism (e.g. Morrisey et al., 2018).

While it is unclear whether the paradigm used here will be adequate for these future research questions, it has successfully established that interacting pairs are processed preferentially. This therefore supports the first hypothesis regarding a larger phenomenon of Social Binding.

Chapter 3:

Social Binding in Spatial Working Memory

Experiment 3a: Distance Judgments of Interacting Partners

The previous experiments examined the initial encoding of social situations during a visual search task where the displays were visible and a target had to be detected. There are of course many other cognitive processes necessary to mediate the processes from perception to coherent goal directed action. This thesis predicts that if encoding of social interactions is fundamental to humans, then these effects of social binding processes will be detected throughout various stages of information processing.

A key subsequent process after locating relevant stimuli is working memory, where after initial encoding a stimulus representation is maintained over some seconds for a subsequent action to be performed (Baddeley & Hitch, 1974; Baddeley, 1992). For example, in classic studies, maintaining a phone number to produce a later motor output when making the call (Severin & Rigby, 1963). Previous work has demonstrated that the emotional properties and task relevance of stimuli influence the nature of these working memory processes, facilitating, impairing or distorting later recall. Observers experiencing anxiety, for example, show greatly reduced spatial memory accuracy (Lavric, Rippon & Gray, 2003) while positive moods improve verbal working memory (Gray, 2001). Indeed, the episodic buffer component of working memory has been shown to bind together features, such as shapes and colors, into objects (Baddeley et al., 2011). Binding is sustained even when the observer does not pay continued attention to the observed objects (Delvenne, Cleeremans & Laloyaux, 2010). This episodic buffer might similarly automatically bind people into interacting groups, facilitating larger capacity for remembered individuals and providing a simplified visual representation to conscious processing.

If the encoding of social information has particular importance to humans, as is hypothesised here, then this should be evident in the nature of the information recalled from short term memory while the stimulus is actively maintained. That is, in accordance with gestalt literature (Coren & Girgus, 1980; Sargent et al., 2010), it is predicted that the effects of encoding social interactions will also be observed in other cognitive processes, especially in recall from memory. Therefore, Experiment 3 investigated distortions of spatial memory when recalling properties of a prior social interaction in an allocentric third-party frame.

The possibility of spatial distortions of reconstructive memory due to higher level information has been shown in egocentric frames where the distance to the participant is the dependent measure. For example, the judged distance between one person (the participant) and another in egocentric space can be modulated by psychosocial factors, such as the relationship of the participant to the perceived other (e.g., Thomas, Davoli & Brockmole, 2014), as well as whether a participant has previously been socially rejected (Knowles et al., 2013; for a review, see Balcetis, 2015). In all these instances, the observer/participant will remember the target as closer or further away from themselves, depending on their emotional state (e.g., fear), properties of the object, and situational cues (e.g., Cole, Balcetis & Zhang, 2013; Harber et al., 2011; Teachman, Stefanucci, Clerkin, Cody & Proffitt, 2008). Critically, it has not yet been studied whether similar distortion effects between social partners can be found in an allocentric framework when observing the interactions between other people and without manipulating the participant's motivation, emotional state, or relevance of the viewed people (e.g., in- vs out-group).

In this new task participants passively observed two individuals on a computer screen and are asked to recall the distance between them a few seconds after the initial view. Participants had no need to actively consider the relationship between the two individuals, so any detected effects would appear to be the automatic computation of the social interaction. The prediction of Experiment 3a was that when participants observe two people in a social interaction, they will recall them as closer together than those individuals who were not interacting.

Additionally, response times were recorded in order to test the prediction that individuals grouped together are encoded into memory as a single "event", which would lead participants to respond more quickly than in cases where non-interacting individuals are encoded separately (e.g. Sargent et al., 2010). This is because the remembered distance between individuals is recalled while one partner is visible on screen. When those partners have previously been shown to be interacting they would, according to Social Binding, have been encoded into memory as one engram. Therefore, the visible person acts as a cue for the entire dyad and the corresponding features (see for example Tulving, Voi, Routh & Loftus, 1983; Woodman et al., 2003; Horner & Burgess, 2013; also see Chapter 4 of this thesis).

Methods

Participants

60 participants were recruited and allocated to the Person experimental (2 male, 28 female) and Wardrobe control (1 male, 29 female) groups. The study was approved

by the ethics committee of the Department of Psychology at the University of York. All participants gave their informed consent prior to starting the experiment.

Materials

Images of two additional models were sourced from the Adobe Stock Service, similar and in addition to the ones from Experiment 1a. The two images of wardrobes from Experiment 2 were also used again in addition to two more pictures of similar wardrobes. The height of all images was normed to 864 pixels, and mirror images for each model were generated so the stimuli could be arranged both facing each other and with their backs turned. See Figure 3.1 for an example of stimulus pictures.

A further picture was taken of an empty section of wall and carpet, to be used as a background on which the stimuli were to be superimposed. Using image manipulation software, all irregularities were removed from the background and a transparent-to-black gradient was applied to the edges to prevent participants from using the stark contrast between the image and the border of the screen as location cues. This background with a sample of stimulus pictures superimposed on it can be seen in the top panel of Figure 3.2. The experiment itself was created using Unity3D (Version 5.2.1f1) and displayed on a ProLite T2735MSC 27-inch touchscreen at a resolution of 1920x1080.

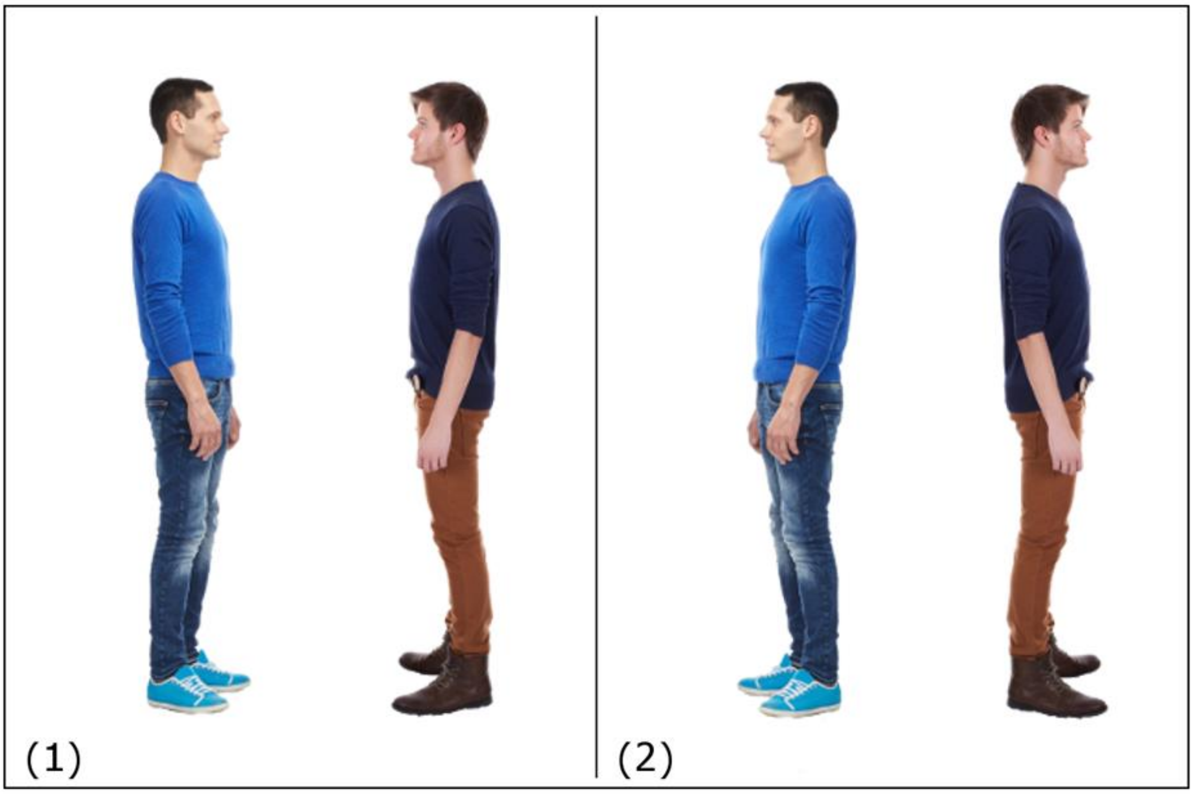


Figure 3.1. Interaction partners in the Towards (1) and Away (2) orientation.

Design

A 2x2 mixed design was used, looking at the effect of orientation of stimuli (Towards or Away; within subjects) and type of stimuli (People or Wardrobes; between subjects) on spatial errors. Spatial error was measured as the fraction of the given distance that the response location was away from the target location (see below). As a second dependent variable, response times of participants were also recorded, measured from appearance of the cue stimulus to the response of the participant.

Procedure

Participants were invited into the experimental room individually. They were handed an information sheet that contained a rough outline of the experiment as well as informing them about their right to withdraw at any point during the experiment. After they consented, they completed a practice version of the experiment together with the experimenter in which they were given instructions before each section on screen. Additionally, the experimenter completed two trials while verbally repeating the instructions and finally the participants were able to practise on two trials while the experimenter made sure that they understood the process. If a participant did not perform the trials correctly or if they expressed that they were not sure about the instructions, the practise session was repeated. If the participant was confident they had understood the instructions, the experiment was started.

Prior to the experiment, participants took part in a calibration session during which they were presented with each stimulus in both left and right orientations three times at different positions on the screen. Each time the participant was asked to use their finger to tap on the centre of the head of the shown individual or the top centre of the wardrobe. The purpose of the calibration session was to establish an individual baseline measure of responses as well as an offset for each stimulus, indicating the difference between perceived and geometric centre. This was necessary in order to exclude the possibility that participants judged the center of the head closer to the face or eyes rather than the geometric center (see Bertossa, Besa, Ferrari, & Ferri, 2008; Starmans & Bloom, 2012 for examples of this). This would have led to an inward-bias in Towards-oriented pairs and an outward bias in Away oriented pairs and therefore presents a confound that needed to be excluded (and was further controlled for in Experiment 4 below). This offset for each stimulus was calculated by averaging the difference between response location and geometric center in the three presentations of each stimulus in each orientation. This was later subtracted from responses collected during the experimental session.

In the main section, participants completed 160 trials. In each trial, they were first shown one of the stimulus pairs in either a Towards or Away orientation superimposed on the background at a random distance from each other. After 3 seconds, both stimuli disappeared to leave an empty background. After one more second, one of the individuals reappeared but in a different position (cue stimulus). Participants were asked to tap the screen where the centre of the head of the other person (target stimulus) would have been if they had also reappeared. The reappearance location of the cue stimulus was constrained in a way that allowed for enough room to indicate the original distance. For a visualisation of the main procedure, see Figure 3.2. At the end of the 160 trials participants were debriefed and received their reimbursement. Altogether the process took 20-25 minutes per participant.

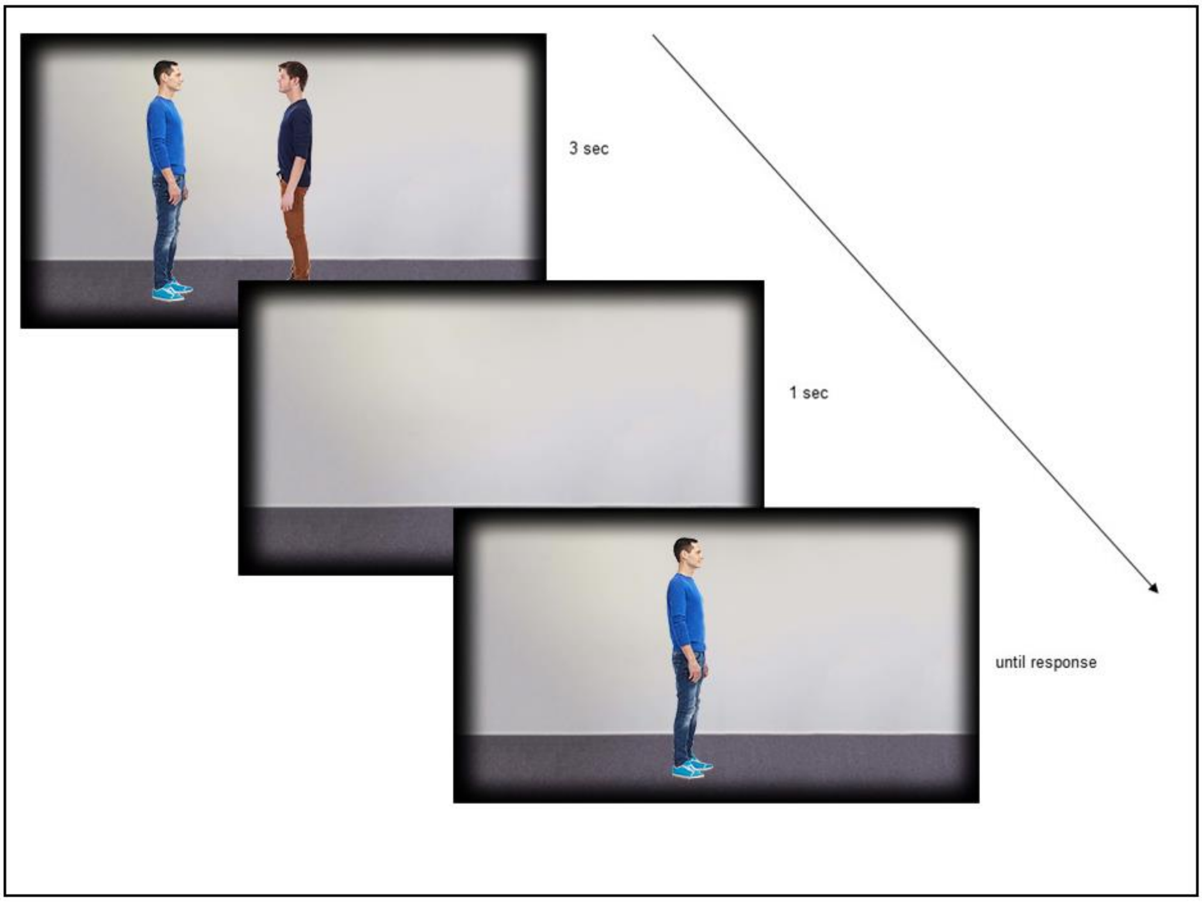


Figure 3.2. Procedure of a Towards oriented dyad with a reappearance of the left partner. Participants were asked to touch the screen where the other partner's head would be if they had reappeared at the same distance from their partner as before.

Data Processing

For each trial, spatial error was calculated according to the formula

$$Error = -\frac{\left((d_s - O_L + O_R) - d_p\right)}{(d_s - O_L + O_R)}$$

where d_s and d_p are the absolute distance given on screen (centre to centre) and indicated by the participant, respectively. O_L and O_R are the offsets for the left and right appearing stimulus established in the calibration session. Negative values indicated that pairs were recalled as closer together than the given distance whereas positive values indicated they were recalled further apart. For example, a spatial error of -0.4 would indicate a 40% shorter distance while a spatial error of 0.6 would indicate a 60% larger distance. A score of 0 represents the participant exactly locating the target.

Randomised stimulus distances were used to make the spatial memory task reasonably demanding. The largest possible distance was 70% of screen width in order to give the re-presented stimulus enough potential to move away from the original location while still allowing for enough space to indicate the full length of the original distance.

Finally, trials in which the participant's response error was more than three standard deviations away from the mean in each group most likely were caused by accidental contact with the touchscreen and were excluded (<2% of trials). Additionally, all trials with response times shorter than 500ms and longer than 5000ms were excluded (<1.5% of trials).

Results

Figure 3.3 shows the mean spatial error for all conditions. Looking first at the spatial error, a 2x2 mixed ANOVA showed no significant effects of orientation ($F(1,58)=1.30$, $p=.259$) or stimulus ($F(1,58)=2.12$, $p=.151$) but a significant interaction between them ($F(1,58)=10.31$, $p=.002$, $\eta_p^2=.151$). Posthoc tests showed the reason for this interaction was that people were remembered as significantly closer in Towards than in Away orientation ($t(29)=3.59$, $p=.001$, $d=0.68$), but no such effect exists for wardrobes ($t(29)=1.30$, $p=.203$).

A 2x2 mixed ANOVA looking at response times (see Figure 3.4) showed only marginally significant effects of orientation ($F(1,58)=3.93$, $p=.052$) and type of stimulus

(F(1,58)=3.60, p=.063) but a significant interaction between them (F(1,58)=5.84, p=.019, η_p^2=.091). Posthoc tests showed that participants responded to person images more quickly when they were in Towards orientation (t(29)=2.92, p=.007, d=0.5) whereas the orientation had no effect when recalling the location of wardrobes (t(29)=0.33, p=.743).

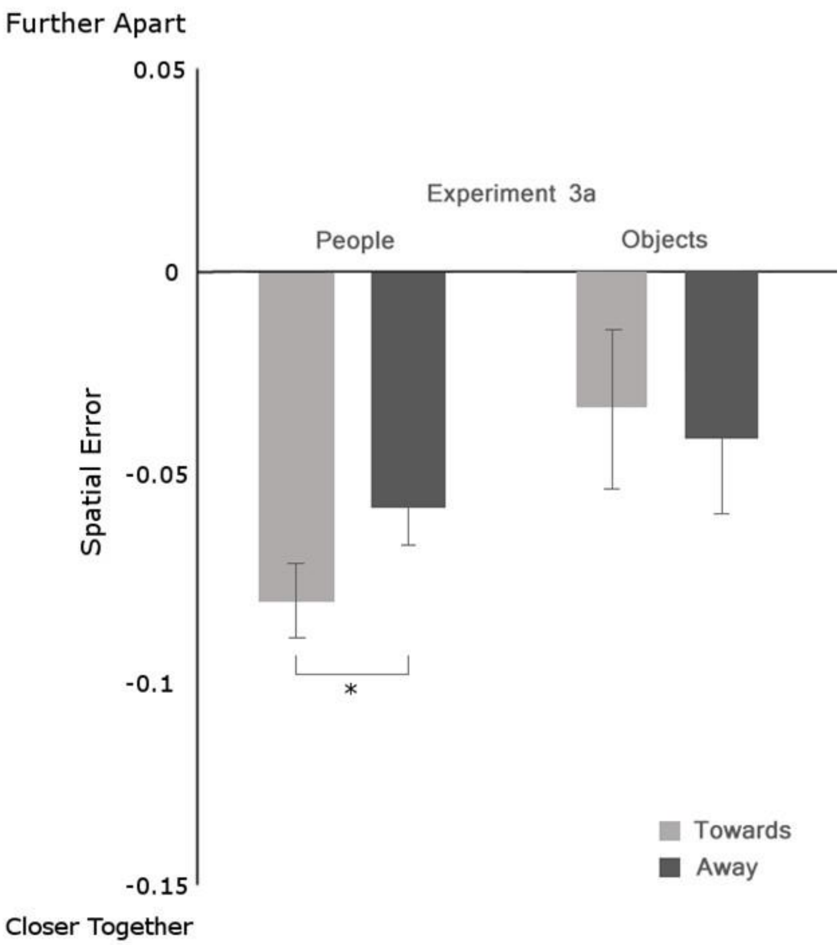


Figure 3.3. Mean spatial error for Experiment 3a. Negative spatial error indicates that stimuli were remembered as closer together. Error bars represent standard error. *p<.05

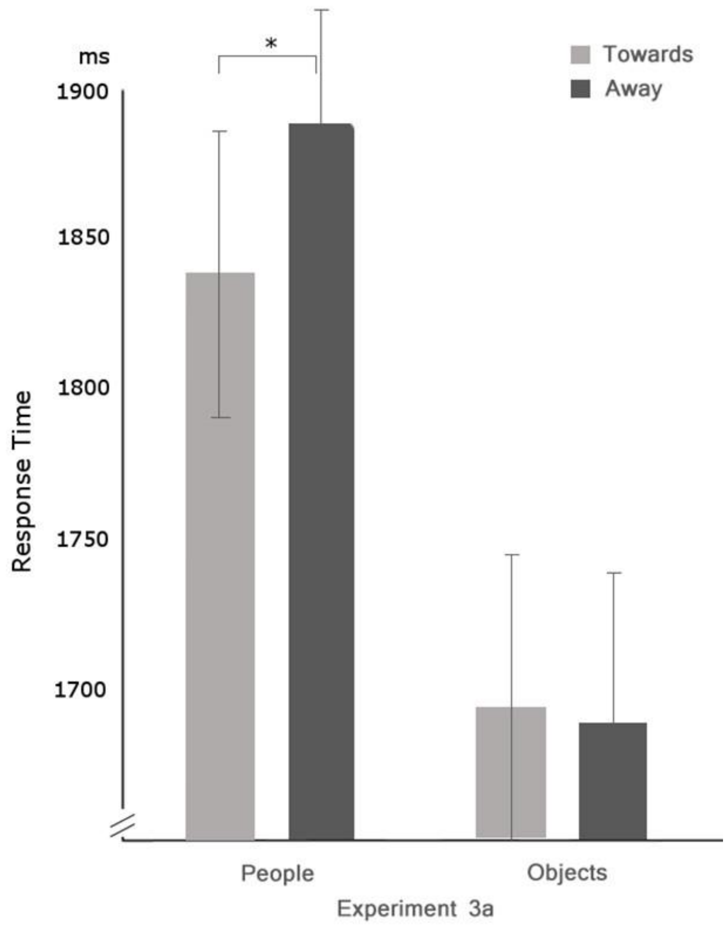


Figure 3.4. Mean response times for Experiments 3a. Error bars indicate standard error. *p<.05

Discussion

It was hypothesised that in a simple short-term memory task where participants were required to recall the spatial location of a person in relation to another one second after viewing the display, such spatial recall could be distorted by whether the individuals were interacting. Two observations suggest that the encoding of social relationships does take place in such passive viewing tasks: First, as predicted, when two individuals are facing each other they are recalled as closer together than when they are facing away from each other. Second, speed to make the location memory response is faster when the two individuals are facing each other. Both observations are consistent with the hypothesis that the two individuals in the implied social interaction, while facing each other, are encoded into memory as one event.

While these first results provide preliminary evidence for Social Binding in spatial memory, there are a range of confounds which could provide alternative explanations and which will need to be ruled out. The most obvious source of potential confounds is the difference in size and shape between the stimulus categories used here and will be further investigated in Experiment 3b while more complex factors, such as standing direction and gaze cues, will be explored in Experiment 4.

Experiment 3b: Row-Scrambled Controls

Experiment 3a has successfully demonstrated binding-like effects for facing persons but not objects. While this is in line with the predictions made by Social Binding, the differences in shape and size between experimental and control stimuli are of concern here: It is possible that the wider shape of the objects combined with a lack of a focus point for participants - provided by the head in the experimental stimuli - increased the variability to a point that differences between orientations are lost in the statistical noise. It is also possible that the center of mass of the entire observed body was removed slightly towards the front and thereby caused participants' responses to be biased towards the looking direction, i.e. inwards for facing pairs and outwards for non-facing pairs. While both confounds are addressed by the calibration used at the beginning of Experiment 3a, it is possible that between this calibration and the subsequent testing participants' focus strayed from the center of the head to the center of the entire presented body. Therefore, a further control is necessary to investigate these possible confounds. The inverted stimuli from Experiment 1 are not sufficient here: It has already been discussed that the body-inversion effect might lead to slower and more detail-oriented processing (Reed et al., 2003; Papeo et al., 2017).

Furthermore, the inversion of the stimuli might shift participants' focus away from the upper body and instead use the feet of the stimulus as a reference point, thereby shifting the center of mass even further. Instead of inverted controls, a row-scrambled version of the experimental stimuli from Experiment 3 was used. This ensured that the controls had the same size and center of mass as the experimental stimuli but without the social component or indeed any directionality at all. If differences in protrusions or center of mass were responsible for the effects seen in Experiment 3, then those would be conserved in these stimuli and seen in this experiment as well. If stimuli were indeed bound due to the implicated interaction between them then no effects should be seen here.

Method

Participants

30 further participants (3 male, 27 female) were recruited for this experiment from the University of York.

Materials

Stimuli were generated by dividing the experimental stimuli from Experiment 3 into 150 rows, which were reassembled in randomised order. See Figure 3.5 for examples. All other materials were identical to those used in Experiment 3a.

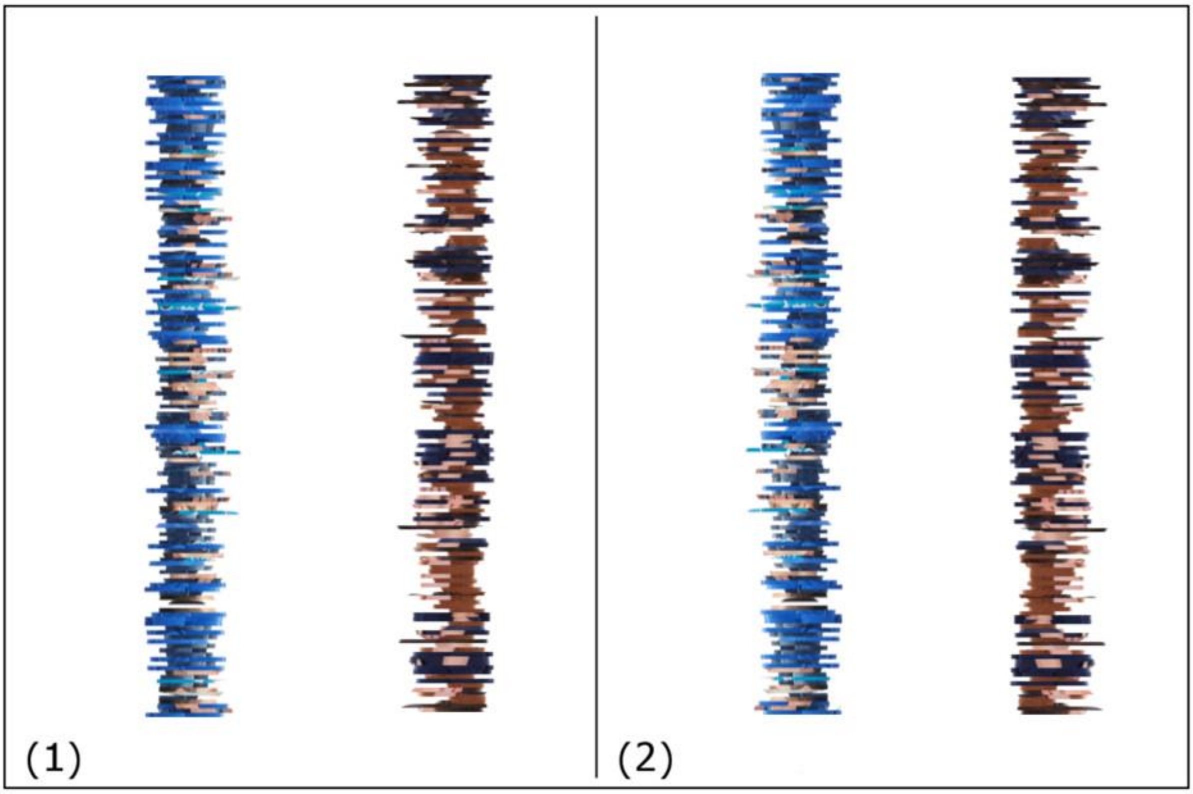


Figure 3.5. Scrambled interaction partners in "Towards" (1) and "Away" (2) orientation.

Design & Procedure

As only one stimulus category was used in this experiment, a simple paired design was used with the only independent variable being Orientation of stimuli (Towards/Away). As before, the dependent variables were spatial error and response time. The procedure was identical to the one in Experiment 3a. Trials featuring response errors more than three standard deviations from the mean as well as response times smaller than 500ms or larger than 5000ms (<2% of trials overall) were removed from further analysis.

Results

A paired t-test showed the difference in spatial error between Orientations to be nonsignificant ($t(29)=1.46$, $p=.156$). There similarly was no significant difference between Orientations in regard to response times ($t(29)=1.06$, $p=.297$). See Figures 3.6 and 3.7 as well as Appendix A for details.

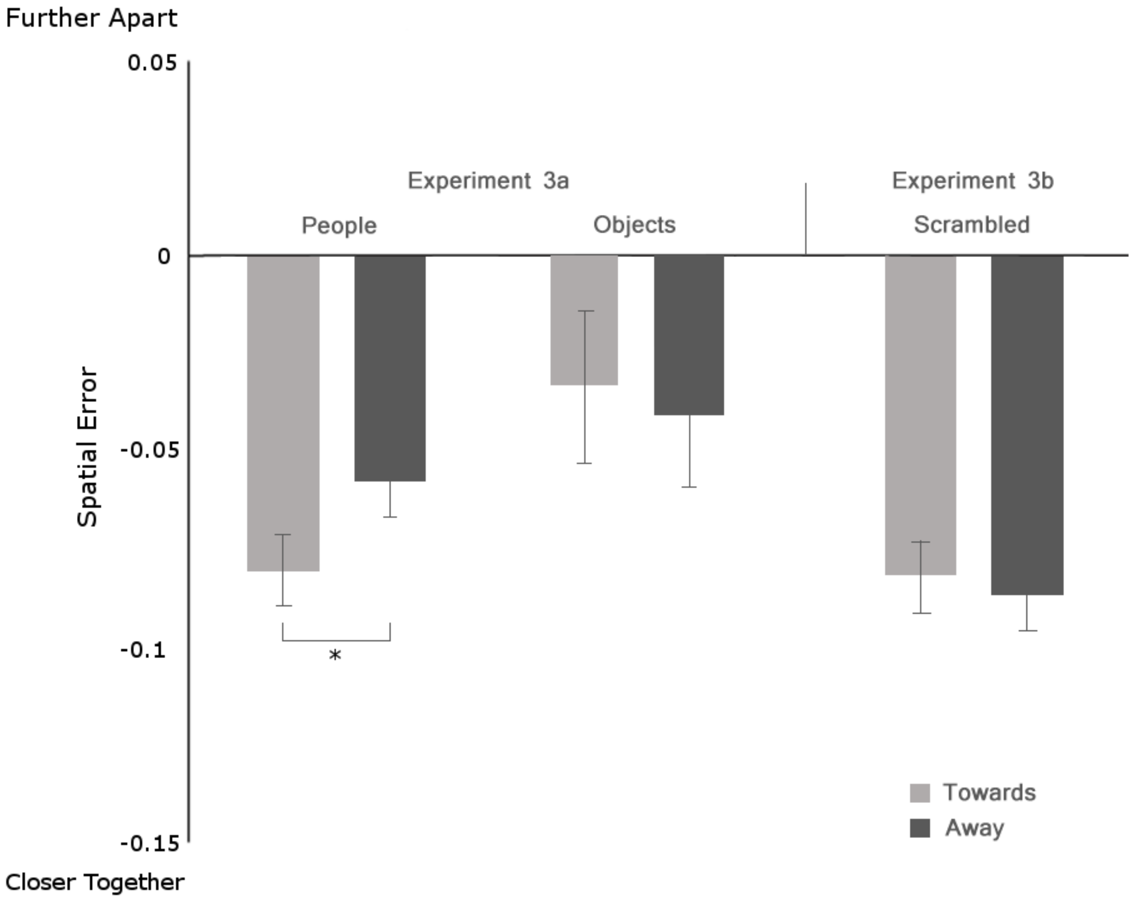


Figure 3.6. Mean spatial error for Experiments 3a (left panel) and 3b (right panel) for all conditions. Negative spatial error indicates that stimuli were remembered as closer together. Error bars represent standard error. *$p<.05$

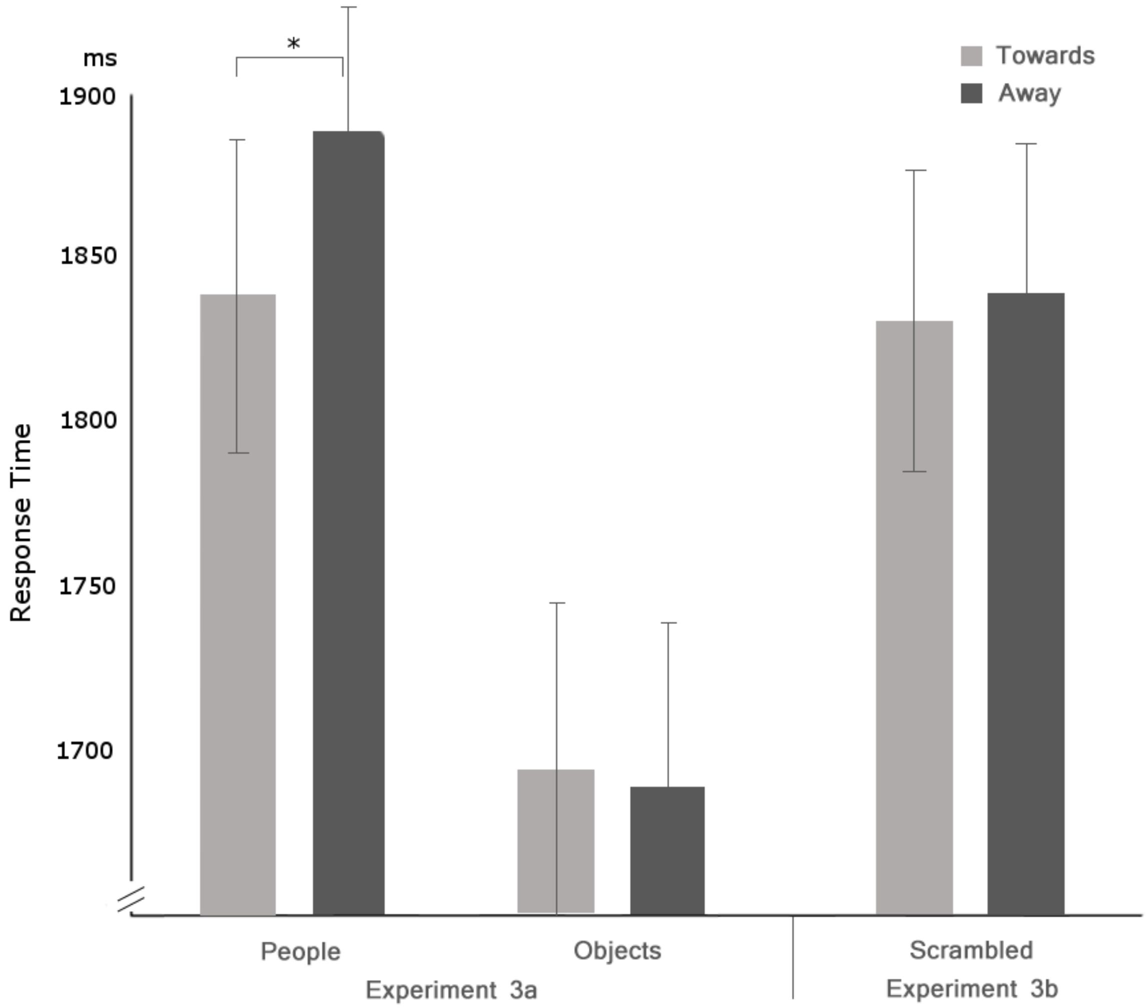


Figure 3.7. Mean response times for Experiments 3a (left) and 3b (right). Error bars indicate standard error. *$p < .05$

Discussion

No differences in either spatial errors or orientation were found for scrambled versions of human stimuli. Hence, there is no evidence of center of mass or any protruding features of the stimuli causing effects comparable to those seen in Experiment 3. While this exclusion of shape or size effects is an important step into ruling out possible confounds, the fact that the stimuli used here did not have identifiable fronts or backs and therefore no facing direction, leaves other properties due to which recall of location could be distorted in the direction of a person's gaze and implied action: These properties are gaze cueing (see Frischen, Bayliss & Tipper, 2007, for review) where attention is automatically oriented to the location another person is seen to gaze towards, and forward models of action prediction (e.g., Wolpert, Ghahramani & Flanagan, 2001) where future states of objects with the potential to move are encoded such that they produce representational momentum-like effects (e.g., Brehaut & Tipper, 1996; Freyd & Finke, 1985; Finke & Shyi, 1988). Experiment 4 will investigate these alternative explanations.

Experiment 4: Same-Direction Controls

This experiment replicates the central manipulation of Experiment 3: That is, when recalling the location of people looking towards each other, this is closer and retrieved more rapidly than when they are facing away from each other. However, the experiment also includes two new conditions to investigate the alternative explanations mentioned above.

These alternative accounts would predict that when recalling the spatial location of a person in the Towards condition, the direction that person was gazing and/or their potential future movements would be encoded. Hence it could be these basic processes that subsequently distort the recall of the location of that person more towards the centre of the image. This effect would not necessarily require the potential social interaction with the other person. Similarly, recall of the spatial location of the person facing away would be a drift outwards, as this is the direction of the attention and potential future action.

The new conditions to examine explanations not based on social interaction, but on gaze and forward predictions, present both people facing in the same direction. These more basic gaze and forward modelling accounts make specific predictions: First, consider the example where both people are facing left. On average all recalled spatial loci should be generally more to the left, whereas when both are oriented to the right all responses should drift to the right. In contrast, when both people are facing in, or both facing out/away, then the average of gaze and forward modelling would be the centre of the display. This is especially relevant in regards to the eye-ward bias mentioned above which, if not entirely accounted for by the calibration, would have led to a drift in responses along the gaze direction of both partners.

The second prediction is more specific, based on whether recall is of the person at the front or the back of these common direction displays. Consider Figure 3.8: When recalling the person at the back, gaze and forward modelling predict that this person will be recalled as closer to the front person. In contrast, when required to recall the person at the front of the pair, they will be recalled as further away. However, the hypothesis based on Social Binding is that because there are no joint social interactions in these latter common direction conditions, then spatial memory is not distorted. In this account, only when a common representation of two people interacting is encoded will spatial memory be distorted. Thus only the Towards condition will produce a contraction of spatial memory, no such effects will be seen in the three other conditions of away, common right or common left conditions.

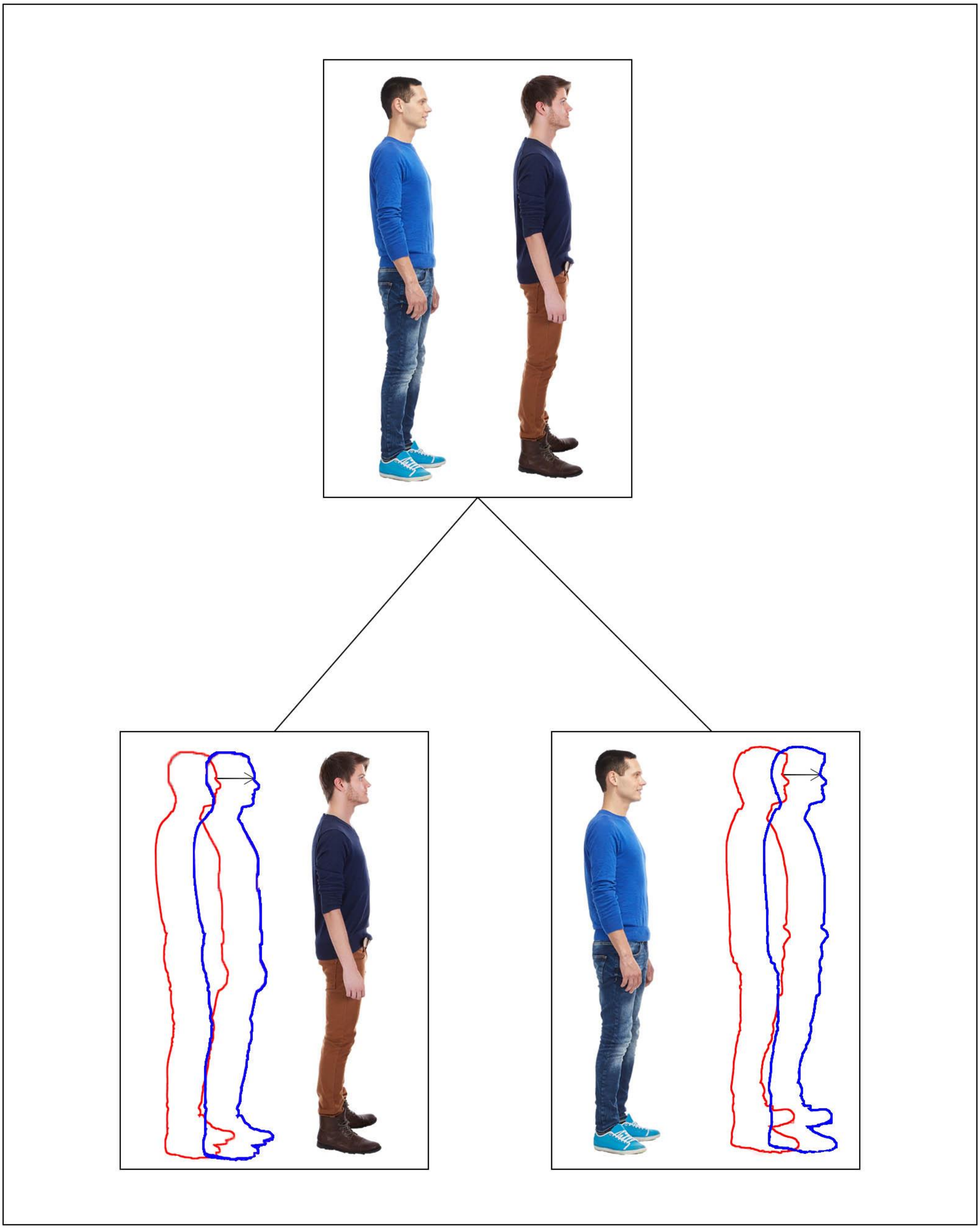


Figure 3.8. If either gaze direction or implied representational momentum of the target stimulus lead to their veridical position (red silhouette) being recalled as further along the direction in which they are facing (blue silhouette), then the same distance between partners (top) would be recalled as being shorter when the target was in the back (bottom left) and larger when the target was in front (bottom right).

Method

Participants

40 participants (37 female, 3 male), all students at the University of York, took part in the experiment and were reimbursed with course credit or a payment of 3 GBP. The study was approved by the ethics committee of the Department of Psychology at the University of York. All participants gave their informed consent prior to starting the experiment.

Materials

The same experimental stimuli as those of Experiment 3a were used with the addition of two more pictures of models of the same sex in the same position. They were arranged into 6 pairs in four different orientations, an example of the latter can be seen in Figure 3.9. Otherwise the same materials were used as in Experiment 3a.

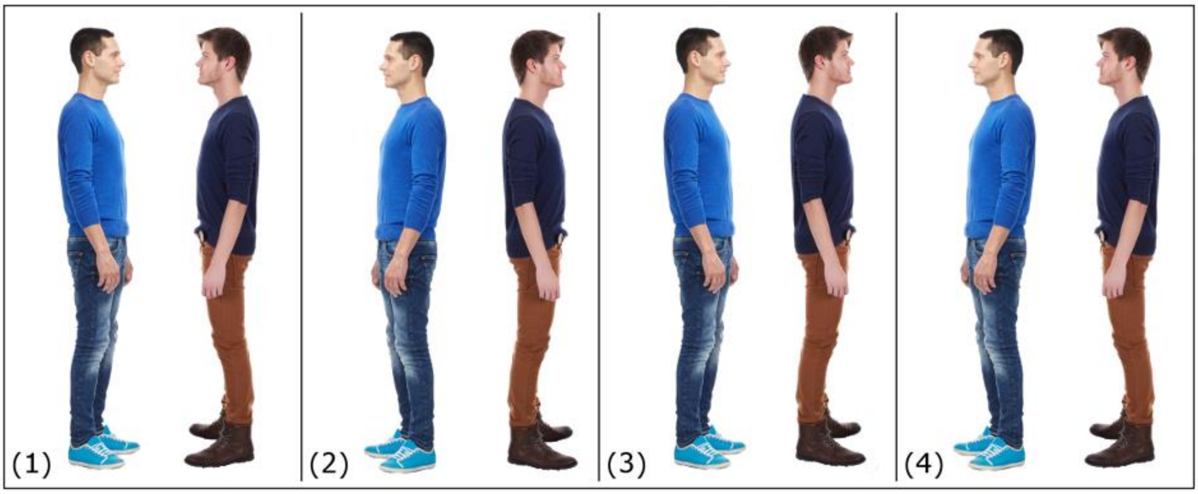


Figure 3.9. Interaction partners in the four orientation conditions (1) Towards, (2) Away, (3) Right and (4) Left.

Design

A repeated measures design was used to test for the effect of orientation (Towards, Away, Right, Left) on spatial error. The effects of orientation on average response location on screen were also tested. A further separate repeated measures test was used to analyse the effects of which partner was recalled (front or back) on spatial error.

Response times, measured from appearance of the cue stimulus to response, were separately analysed and compared depending on orientation of the dyad and whether the attended (front) or unattended (back) partner had to be recalled.

Procedure

The procedure was identical to that of Experiment 3. Trials with response errors which were further than 3 standard deviations from the mean as well as those with response times below 500ms and above 5000ms were excluded (<4% of trials).

Additionally, all trials in which the participant accidentally placed the target on the wrong side of the cue stimulus were removed (<1% of trials).

Results

Figure 3.10 shows the mean spatial error as well as response times across all four conditions. To test whether the previous results were replicated, a repeated measures ANOVA was carried out, which showed that orientation (Towards, Away, Left, Right) had a significant effect on response errors ($F(3,117)=9.48$, $p<.001$, $\eta_p^2=.434$). Pairwise comparisons with Bonferroni corrections revealed that people were remembered as having been closer together in the Towards orientation as compared to all other orientations (all $p<.05$), but no differences were found in response error between the Away, Left and Right orientations (all $p\geq.26$).

Response times were compared using a repeated measures ANOVA to test for effects similar to those of Experiment 3a. Differences in response times depending on orientation of the pair were significant ($F(3,117)=10.66$, $p<.001$, $\eta_p^2=.464$). Participants responded on average 43ms more quickly in trials involving Towards oriented stimuli as compared to all other conditions (all $p<.05$) with no differences found between the remaining conditions (all $p>.9$).

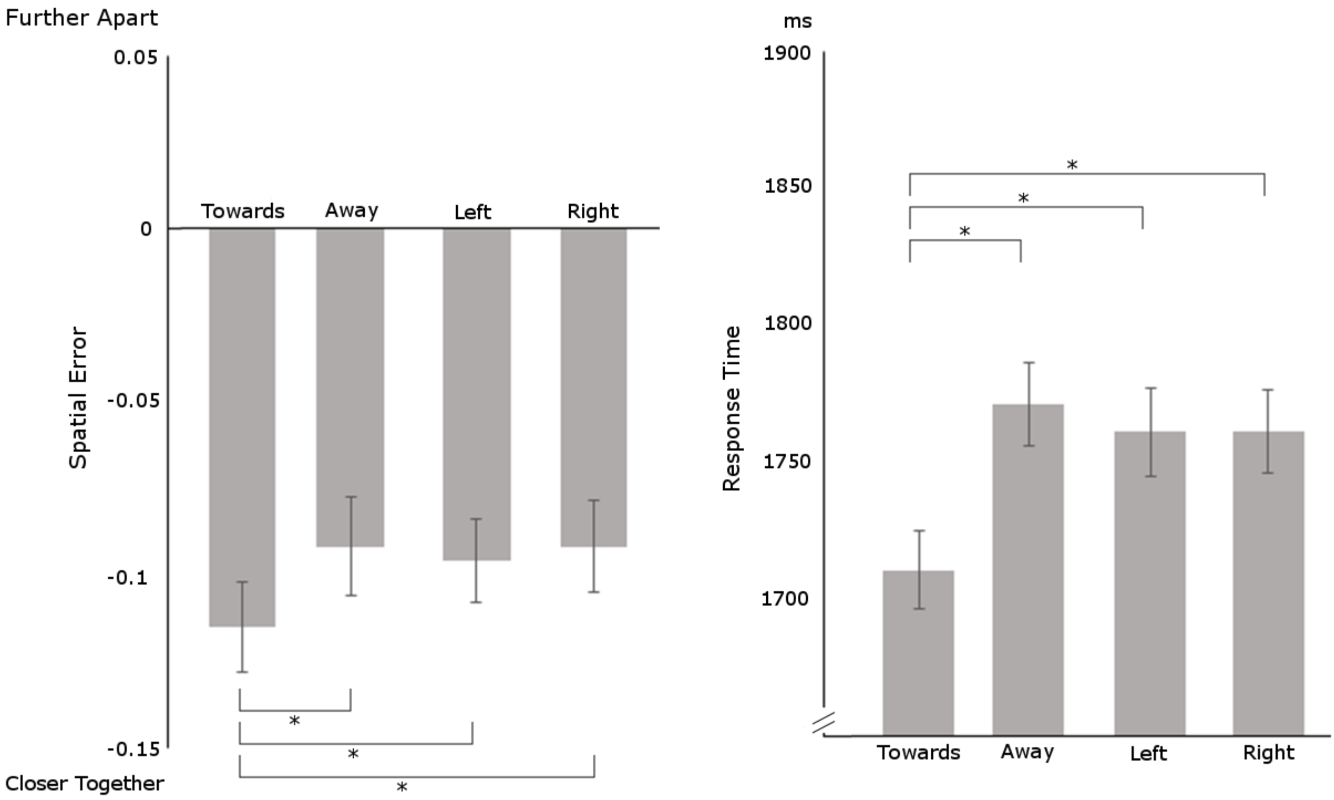


Figure 3.10. Mean spatial error (left) and response times (right) for the four orientation conditions Towards, Away, Left and Right. Error bars indicate standard error. **p*<.05

Possible gaze cueing effects were tested using a paired samples t-test on the Left and Right facing conditions to compare the response errors that resulted from remembering either the front or back interaction partner (Towards and Away conditions did not have a front or back partner). There was no difference in distance recall between trials that prompted participants to recall the front partner or the back partner ($t(39)=0.93$, $p=.179$) in the conditions where both people faced the same direction. Means can be seen in Figure 3.11.

Whether the fact that the target area was gazed at by the shown partner had any effect on response times was tested using a paired samples t-test to compare the response times depending on whether the trial prompted the recall of the attended (front) partner and therefore involved a target location within the gaze direction of the visible partner. Reaction times did not differ significantly between response locations that were in the gaze direction of the cue stimulus and those that were not ($t(39)=0.01$, $p=.496$).

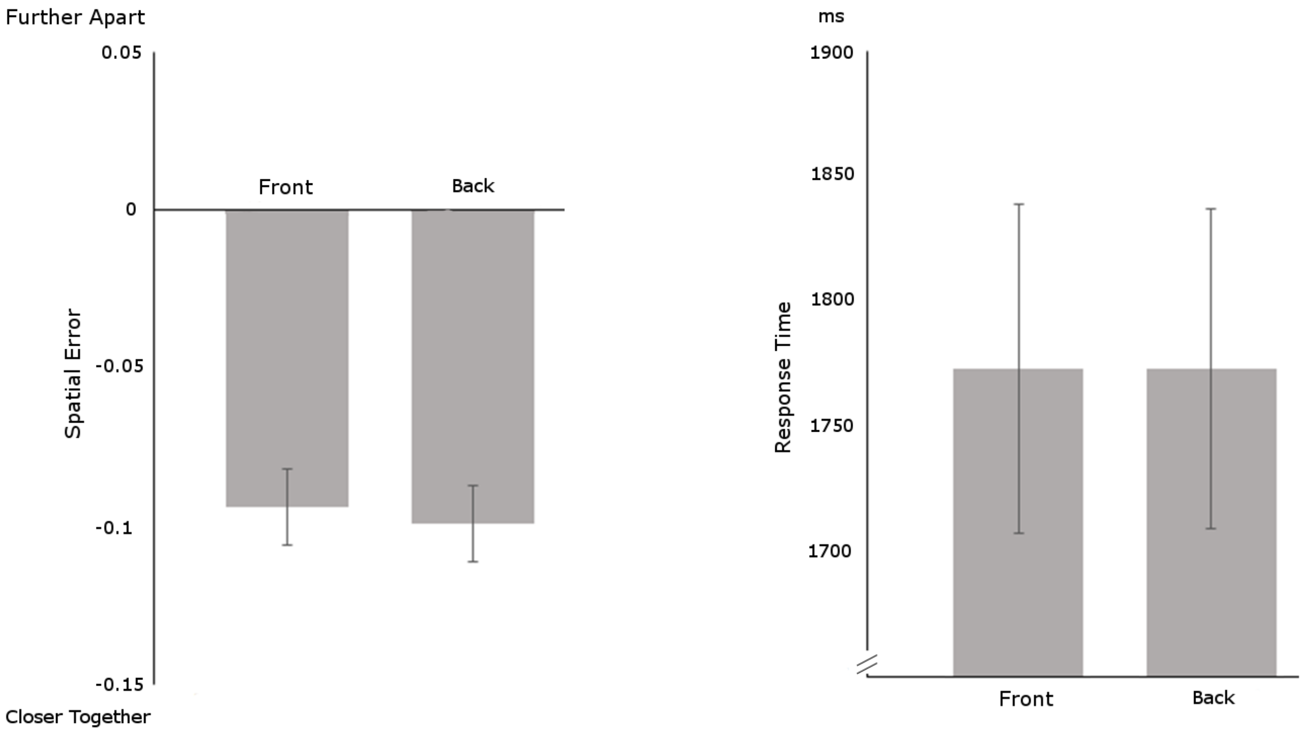


Figure 3.11. Mean spatial error (left) and response times (right) for conditions in which participants were prompted to remember the location of the front or back partner. Error bars indicate standard error.

A further repeated measures ANOVA tested general response location distortions to the left or right by comparing the averages of indicated response location on screen of all orientations. There was no effect of orientation on the average target location ($F(3,117)=0.58$, $p=.63$). Additionally, a post-hoc one-sample t-test showed that the target location averaged across all conditions was not significantly removed from the screen centre ($t(39)=0.92$, $p=.18$).

Discussion

This experiment has clearly replicated the findings of Experiment 3a. That is, when people are viewed looking towards each other implying a social interaction, they are recalled as closer together and access to this spatial memory is facilitated as reflected in shorter response times. However, this study also tested alternative accounts. The orienting of attention via gaze cues, and forward modelling of possible future action states, made specific predictions in the conditions where both individuals faced in the same direction. First, overall recall of spatial location will shift in the common direction when people face the same way; and second, there would be asymmetric recall, where the back person is recalled as closer to the front person, whereas the front person would be recalled as further away from the back person. None of these effects that would support an alternate explanation have been found and therefore it seems that the weight of evidence produced by the experiments in this chapter at this time supports the proposal that the spatial memory distortions seen in Experiment 3a occur only for socially interacting people and therefore presents more evidence in support of Social Binding.

Chapter 3 - General Discussion

The experiments presented in this chapter have shown clear evidence for spatial distortions in agreement with the predictions made by Social Binding: People facing each other are later recalled to be closer together than those facing away from each other; whereas, in sharp contrast, these differences in orientation did not exist for inanimate objects with clear fronts and backs. Confounds on the basis of center of mass and protrusions towards the front were ruled out. Further possible confounding factors based on gaze cues and representational momentum were also found to not have any systematic effects. The most likely conclusion therefore seems to be that the observed spatial distortion effects are caused by Social Binding of the dyads due to their implied interaction.

The present response time advantage for facing social dyads is similarly interesting: As these advantages are only present in the socially interacting stimuli, it seems that one individual will act as a cue for the retrieval of the dyad if the partners were facing each other and therefore been bound into memory as one engram (Woodman et al., 2003; Tulving et al., 1983). This finding leads to the studies in the following chapter that investigate longer-term incidental memory retrieval.

As identified in the experiments reported in Chapter 2, where the potentially socially richer man-child interaction produced substantially larger effects on visual search performance, further research could focus on the quality of the interaction between partners, rather than just whether or not an interaction is present at all. Stronger associations between partners might lead to increased binding effects and therefore stronger spatial distortion and potentially decreased response times. Just as with the previous experimental paradigms, it is possible that experience, expectations and cognitive biases may lead to differences in spatial distortions, such that, for example, members of the same group are remembered closer than members of different groups.

It would be especially interesting to further investigate the relationship between the spatial distortion and response time advantage. While both are theorised here to be consequences of the same general phenomenon, it is possible that they can be dissociated from each other in that response times might be a direct consequence of association strength in memory whereas spatial distortions result from more high-level further processing of the memory engram where the above mentioned biases and expectations are applied when reconstructing the memory. Moreover, spatial errors being dependent on high-level computations is reminiscent of findings of spatial distortions when observing emotionally salient stimuli from an egocentric perspective (e.g. Harber et al., 2011; Balcetis, 2015). Similar effects of threat, desire, approach and avoidance might be found here as well. Chapter 5 will present an initial investigation into such effects.

It was noted that lower-level Gestalt grouping processes can influence retrieval from working memory. Overall, the results in this Chapter support a Social Binding model where high-level computations of social interactions are undertaken. These processes lead to the spatial contraction of information retrieved from memory as well as facilitated retrieval as reflected in faster response times.

Chapter 4:

Social Binding in longer-term Visual Memory

After Chapter 3 observed binding effects in short-term working memory it is prudent to ask whether longer-term visual memory also shows effects consistent with Social Binding. Longer-term memory here refers to episodic memory of individuals and groups that have previously been observed interacting. Remembering specific persons, their features, behavior and interactions is of course vital for everyday life by making it possible to recognize individuals, understanding their relationships with others and predicting their actions.

Previous studies have shown increased recall accuracy for emotional (Hamann, 2001) and arousing (Bradley, Greenwald, Petry & Lang, 1992; Kensinger, 2004) stimuli, although the mechanisms of this modulation are still uncertain and disputed (Dougal & Rotello, 2007). Socially salient stimuli, such as faces, are similarly showing increased recall accuracy, particularly those belonging to the same group as the observer (Meissner & Brigham, 2001), those that are pleasant (Cross, Cross & Daly, 1971) or those that are perceived by an anxious observer to have negative expressions (Foa, Gilboa-Schechtman, Amir & Freshman, 2000).

It is further known that features of an event or simultaneously presented information is strongly associated in memory and stored as a cohesive unit or "chunk" (e.g. Horner & Burgess, 2013), leading to increased recall accuracy and speed of one feature in the presence of another that is part of the same event. In the context of observed social interactions, this would imply that interacting persons are stored in memory as one group rather than separate individuals. This would allow for fast recall of related individuals and further facilitate abstract cognitive representations of these groups by combining and averaging the features of the group members.

In light of previous research showing increased recall for perceptually bound features that are not directly relevant to the binding process (e.g., Woodman et al., 2003; Horner & Burgess, 2013) it can be predicted that retrieval accuracy is increased in individuals that were initially presented as members of Towards-oriented pairs rather than Away-oriented pairs. That is, the experiments in this chapter directly test the idea that individuals who are perceived to be interacting while facing each other are represented in a coherent combined form that facilitates encoding into and retrieval from memory. To this end participants are presented the same spatial judgments task as in Chapter 2, followed by a surprise memory task. As participants were unaware that there would be a memory recall task until the end of the experiment after the spatial task was completed, any encoding into memory during the spatial task was incidental.

Experiment 5: Memory for Pair Membership

During this memory task participants are asked to recall the individuals that made up each pair that they had seen before. To this end they were presented with pairs of individuals that either had been part of the same or different pairs during the spatial judgments task. In line with the central hypothesis that grouped individuals are bound into memory as a single event, the prediction is that recognition accuracy for those individuals that previously had been shown in Towards-orientation should be increased compared to individuals who had been seen in Away-orientation (Horner & Burgess, 2013). Response times were also recorded to examine whether speed, as well as accuracy of recall, was also affected, although speed of response was never emphasized as a task goal to participants.

Method

Participants

40 participants (37 female, 3 male) were recruited from the student population of the University of York and reimbursed with course credit or payment.

Materials

The same pictures of upright standing individuals in side profiles as in Experiments 1, 3 and 4 were used but the stimulus pool was extended to include pictures of 20 men and 20 women in order to present enough different features for the participants' memory to be tested. All stimuli can be seen in Appendix B.

Design

For the spatial task a paired t-test was used to test for the same effects seen in Experiment 3: Differences in spatial error and response times between orientation of stimuli (Towards or Away). For the memory task, a paired t-test was used to test for differences in retrieval accuracy and response time according to orientation of stimuli (Towards or Away). Response times were measured starting from the appearance of the stimulus until the participant made their recall decision by pressing one of the response buttons.

Procedure

The experiment was carried out in two parts: a spatial judgments task as in Experiments 3 and 4, followed by a surprise memory task.

The spatial judgments task was identical to Experiment 3 with minor alterations to the stimuli: Stimulus individuals were divided into 10 male and 10 female pairs. Of those, 5 male and 5 female pairs were shown exclusively and repeatedly in Towards orientation with the remaining 5 male and 5 female pairs always shown in Away orientation. This was counterbalanced between participants. Looking direction of every individual was held constant throughout this part of the procedure (but counterbalanced between participants) as this was a part of the subsequent memory task. Each pair of people was shown exactly four times in the spatial recall task, yielding 80 trials per participant. Each person was the spatial recall target twice.

Immediately after the spatial judgments task followed a surprise memory task. Participants were informed that their memory for the stimuli they had observed in the first part was to be tested (this was not mentioned to them before). They were informed that they had seen 20 pairs in the first part and that each pair was always made up of the same two individuals. They were to now see 20 pairs again, some of which might be made up of two individuals that formed a pair in the first task, some consisting of two individuals that were part of different pairs in the spatial task. See Figure 14 for an overview of the possible retrieval cues. Pairs appeared in the same orientation as in the spatial judgments task. Participants were asked to indicate for each pair whether they had seen it in this constellation before or whether the individuals had been part of different pairs by pressing the 'c' or 'v' key respectively (counterbalanced between participants). As response time was only a secondary measure participants were not asked to respond as quickly as possible but rather only told to not overthink their response. The entire procedure took no more than 20 minutes after which participants were fully debriefed.

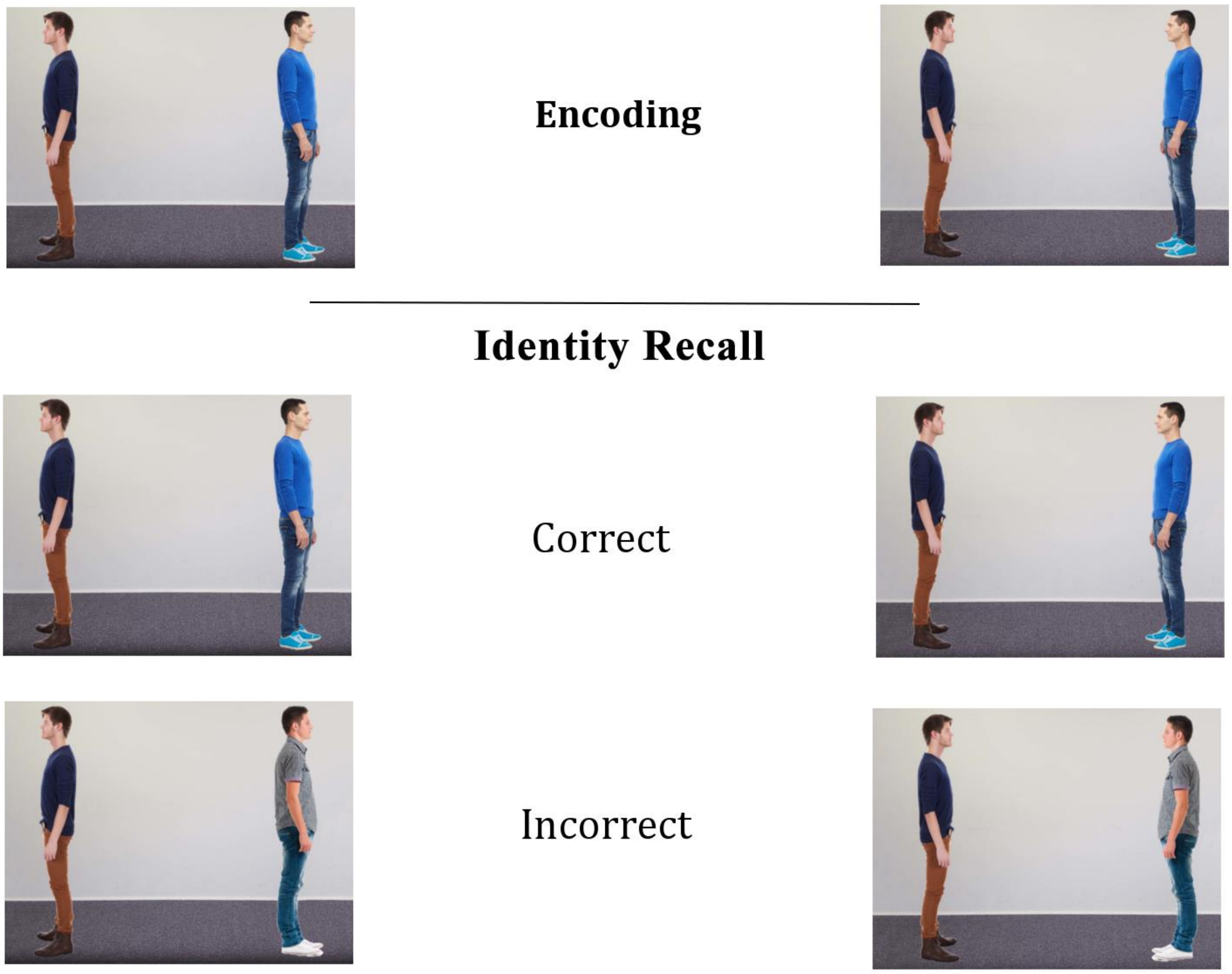


Figure 4.1. An example of an encoded pair in Away (left) and Towards (right) orientation with the corresponding possible retrieval prompts.

Results

Spatial Judgments

In order to test whether the spatial distortions found in Experiments 2a and 2b were replicated, spatial error and response time differences between Towards and Away oriented pairs were investigated across all 40 participants. As before, trials where participants placed the target on the wrong side of the cue stimulus and those that were more than 3 standard deviations away from the mean were excluded (<1% of trials).

As expected, Towards oriented pairs were remembered as closer together than Away oriented pairs (t(39)=3.04, p=.004, d=0.48) as well as processed faster (t(39)=2.73, p=.009, d=0.43); replicating again the findings from Experiments 3 and 4. See Figure 4.2 for details.

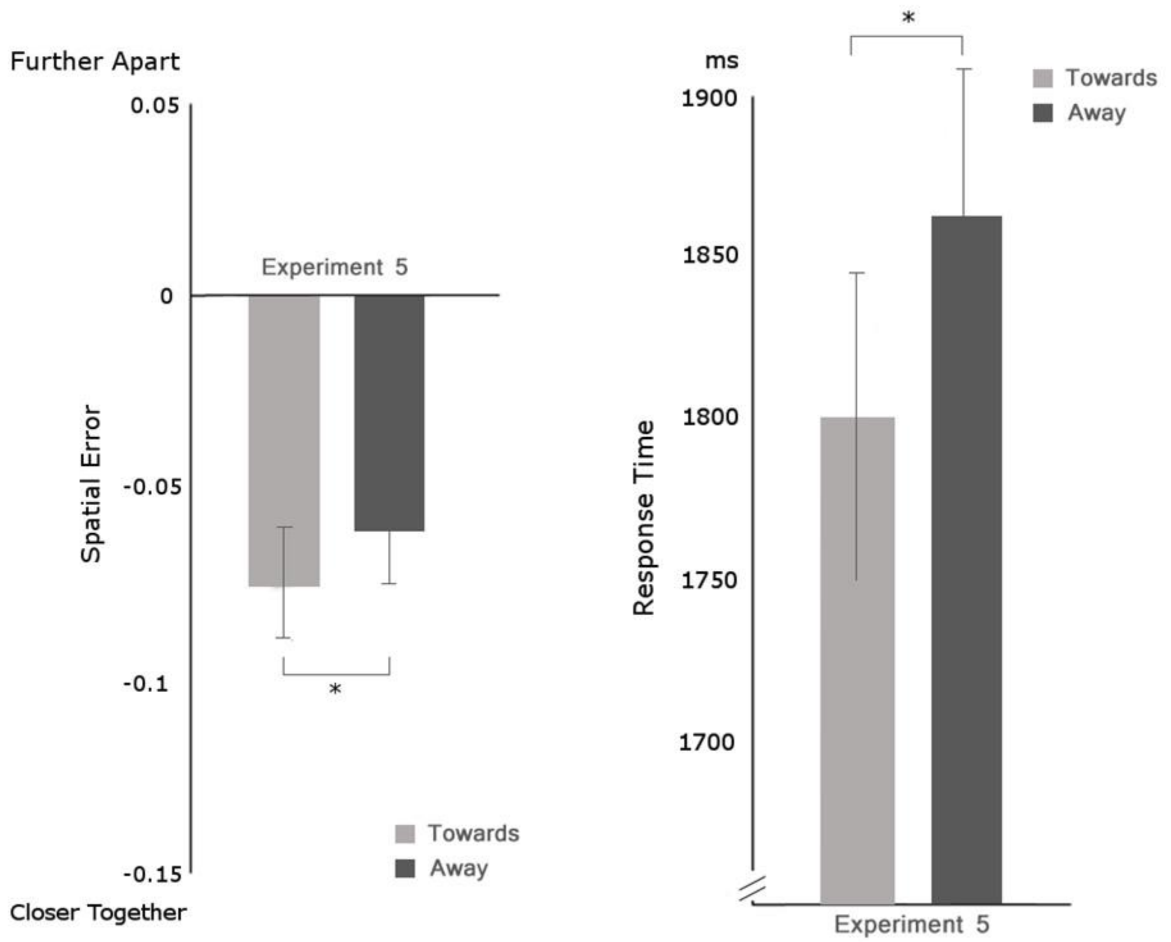


Figure 4.2. Mean spatial error (left panel) and response times (right panel) for Towards and Away oriented pairs in Experiment 5. *$p<.05$

Visual longer-term Memory

Binomial tests (.50) confirmed that participants performed significantly better than chance in the memory task, both when stimuli were shown in Towards as well as Away orientation (p<.05). As can be seen in Figure 4.3, pairs in Towards orientation were on average remembered 6.5% more accurately than those in Away orientation (t(39)=2.92, p=.006, d=0.46). A t-test considering only the correct responses did not reveal any significant differences in response times (t(39)=0.03, p=.977).

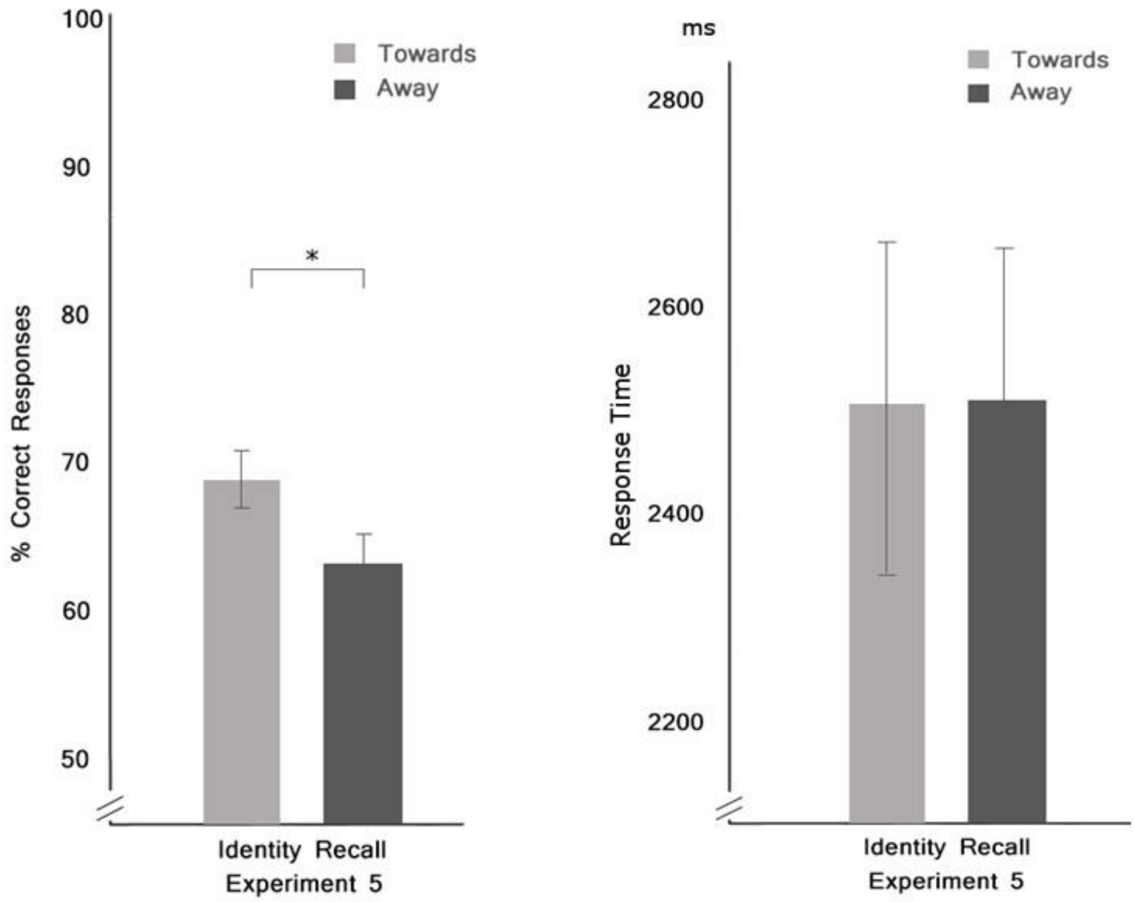


Figure 4.3. Mean retrieval accuracy of participants in all recall conditions. Error bars represent standard error. *p<.05, **p<.001

Discussion

The findings of increased retrieval accuracy for previously interacting pairs is consistent with the predictions and in line with results expected if Towards-oriented individuals are bound into memory as a single event. Response times were seemingly not affected by orientation of individuals even though individuals were still in Towards or Away orientation during the memory retrieval task. This might be due to the nature of the task with participants taking the time they need to make a decision without having been told to be as quick as possible. It is also possible that the individual-level processing necessary to analyse the partners of each pair eliminated all binding benefits that were the result of processing of the dyad without processing of the individuals.

Because these longer-term memory effects are reported here for the first time, it is essential that they are extended and replicated. Note that the person identity property recalled here was irrelevant to the previous spatial recall task, hence the social binding processes produces encoding effects that appear to be automatic. The next experiment examines whether other properties, such as orientation and color, are also encoded into memory more efficiently when perceiving social interactions. A further need for extension to the current study concerns the nature of the stimuli employed in the final recognition task. These stimuli were the same as those perceived during initial encoding during the previous spatial recall task. That is, pairs of individuals either facing Towards or Away from each other. Therefore an important issue is whether the facilitated recall in the Towards condition can also be observed when the stimuli during encoding (spatial recall task) and those during subsequent retrieval, are different; and where the stimuli during recall are identical for the Toward and Away condition.

Experiment 6: Memory for Orientation and Color

Previous research has suggested that memory for objects within a perceptual group is enhanced even for features that are not relevant at the group level and even differ between objects (Woodman et al., 2003). Therefore, the current experiment investigated whether memory for individual details that are not uniform across partners also benefits from Social Binding. In this experiment there are two properties of the Toward and Away conditions that are subsequently examined, these properties are referred to as group relevant and irrelevant features. However, it is important to note that both of these stimulus properties were irrelevant to the initial spatial recall task, and hence any memory advantages during social binding in the Towards condition reflect incidental/automatic encoding into memory.

The group relevant stimulus property was recall of the direction that a previously viewed person had been facing in the earlier spatial memory task. Although this property was not explicitly considered in the previous spatial task, direction an individual faced was of course a necessary feature determining whether the individuals were grouped due to social interactions (Towards) or not (Away condition). For the group irrelevant feature, recall of the color of an individual's clothing was chosen as this was neither relevant for computing social interactions nor a common feature of any pair.

If individuals in Towards-orientation are bound into groups then participants should recall the looking direction better and more quickly for those individuals as compared to those that had been presented in the Away orientation. Predictions for the clothing color recall task are less clear: On the one hand, a stimulus feature such as color might be recalled more easily and quickly in Towards-oriented pairs if the grouping is beneficial to individual features; on the other hand it is possible that the effects of social grouping determined by the property of Towards or Away orientation, might inhibit irrelevant features such as clothing color and hence there will be no recall advantages in the Towards condition.

There is even the possibility of a decrease of recall accuracy due to possible unitization (McLaren & Mackintosh, 2000; Welham & Wills, 2011), which has been shown to distort memory of features such as size towards the corresponding feature of the partner or the group average (Im & Chong, 2014; Corbett & Oriet, 2011; Corbett, 2016). While this would be an interesting effect in its own right, the current study aims at establishing Social Binding in the absence of secondary effects and this kind of memory distortion would therefore have presented a confound. Therefore the experiment has been designed to decrease the possibility of this effect as much as possible, as described in the materials and procedure sections below.

Method

Participants

60 participants were recruited and allocated randomly into task-relevant (looking direction; 30 female) and task-irrelevant (clothing color; 30 female) memory conditions. All participants were tested for color vision deficits with the Ishihara test (Clark, 1924) after the experiment; No participant showed such deficits.

Materials

The same stimuli as in Experiment 3a were used. Three variations of each stimulus person were produced that differed in color of clothing. In order to avoid potential color averaging effects between partners, colors were chosen that were perceptually very different for the corresponding clothing items between partners. Additionally, which clothing items would change color between partners was varied, e.g. one individual's shirt versus another's trousers. See Figure 4.4 for an example. Otherwise the same materials as in Experiment 5 were used.

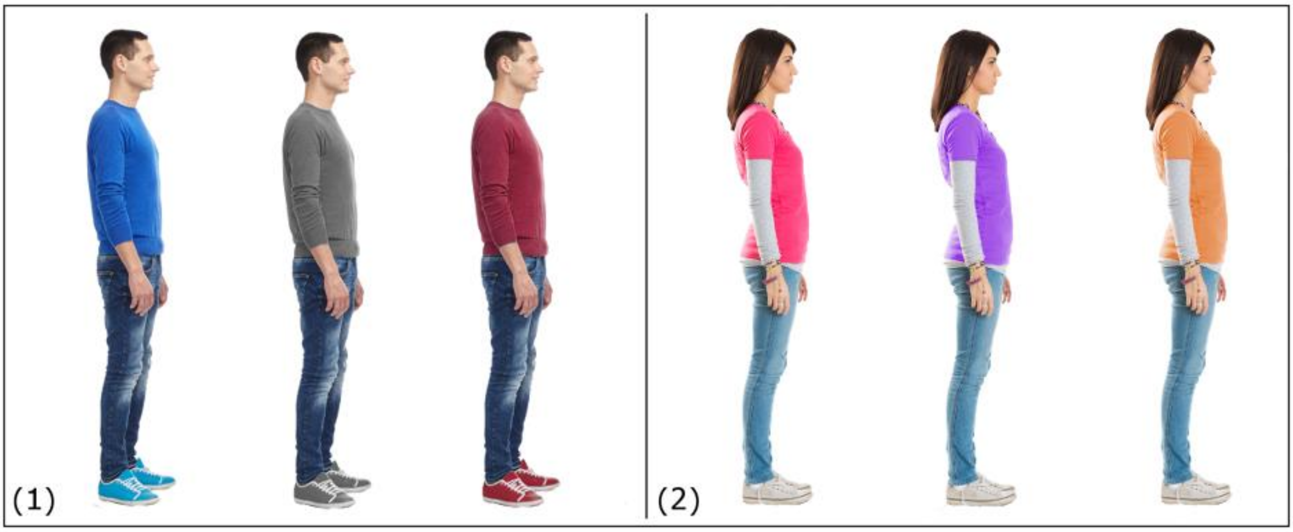


Figure 4.4. Three color variations of both a male (1) and female (2) model.

Design

The spatial task was analysed in the same way as in experiment 5. For the memory task a mixed 2x2 ANOVA was used, looking at the effect of orientation of stimuli (Towards or Away; within subjects) and type of recall (group relevant direction or group irrelevant clothing color; between subjects) on response time and retrieval accuracy in a surprise memory task. Accuracy was represented by the percentage of correct responses.

Procedure

This experiment again used a spatial judgments task followed by a surprise memory task. The spatial judgments task was identical to Experiment 5. For participants in the color memory condition, one of the color variations was chosen at random for each stimulus individual at the beginning of the experiment.

At the start of the surprise memory task, participants in the looking direction condition were informed that all individuals in the first part of the experiment always faced in the same direction. They were further told that they would now see all previously viewed people again individually on screen. Participants were asked to indicate whether the individual was looking in the same or in the opposite direction as before by pressing the ‘c’ or ‘v’ key on the keyboard (counterbalanced between participants). Exactly half of individuals were shown in their original orientation and half in the opposite orientation (counterbalanced by gender and orientation).

Participants in the color memory condition were informed that they would see each individual from the first task again, but for each they would see two versions that differed by the color of their clothing, the correct one and one of the two alternates. They were asked to indicate which version they had seen before by pressing the ‘c’ key for the left version and the ‘v’ key for the right version. Response keys were not counterbalanced in order to avoid Simon task effects (Simon & Wolf, 1963). Exactly half of correct stimuli appeared on the left, half on the right side of the screen (counterbalanced by gender and orientation). While in the interest of accuracy participants were not asked to make their decisions as quickly as possible, they were told to "not overthink it but just go with [their] first instinct". See Figure 4.5 for an overview of the two memory tasks with their possible retrieval cues.

The intention behind measuring color recall in the form of a two-alternative forced-choice task that always included the correct choice was to counteract any memory distortions resulting from unitization. That is, participants might have misattributed features of one member of a socially bound dyad to the other. The presence of the correct choice was intended to minimise such feature misattribution. See Experiment 7 for a further investigation of this possibility. The direction recall condition, however, necessarily used the same single-target recognition task as in Experiment 5 because a 2AFC task like in the color condition would have presented both the left and right orientation of each individual at the same time, which between them would have formed Together- or Away-oriented pairs, which in turn would have introduced additional confounds. Due to this difference between conditions it is necessary to recommend caution when comparing the overall main effects or effect sizes between the direction and color condition. However, this difference is not relevant to the hypotheses investigated here as it only concerns the orientation differences within conditions, not the overall performance between conditions.

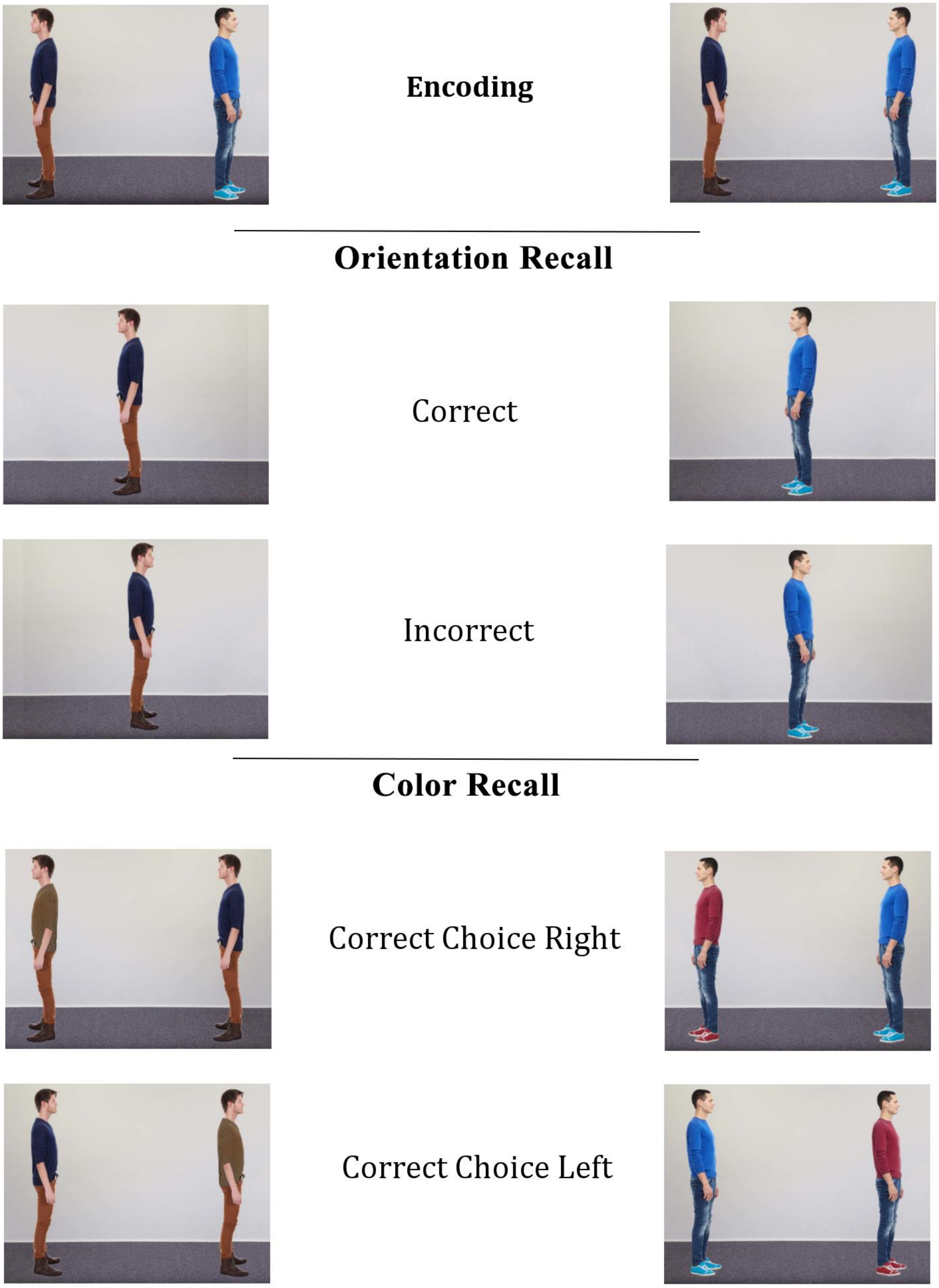


Figure 4.5. An example of an encoded pair in Away (left) and Towards (right) orientation with the corresponding possible retrieval prompts.

Results

Spatial Judgments

In order to test whether the spatial distortions found in Experiments 3, 4 & 5 were replicated, spatial error and response time differences between Towards and Away oriented pairs across all 60 participants were investigated. As before, trials where participants placed the target on the wrong side of the cue stimulus and those that were more than 3 standard deviations away from the mean were excluded (<3% of trials).

As expected, Towards oriented pairs were remembered as closer together than Away oriented pairs ($t(59)=2.83$, $p=.006$, $d=0.36$) as well as processed faster ($t(59)=2.80$, $p=.007$, $d=0.37$); replicating again the findings from Experiments 3, 4 & 5. See Figures 4.6 and 4.7.

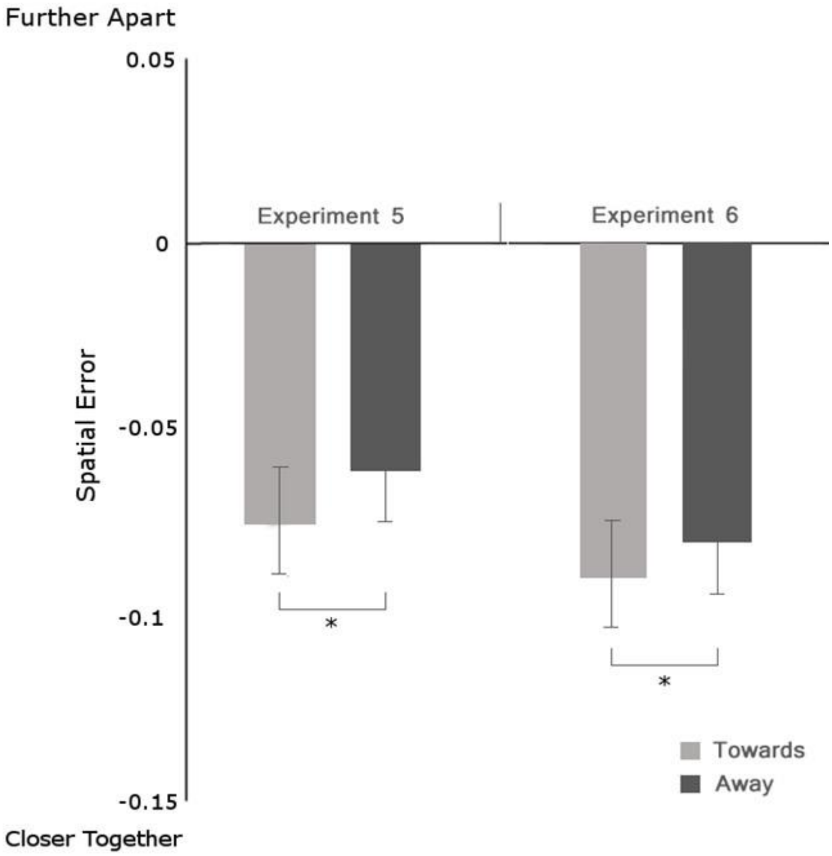


Figure 4.6. Mean spatial error for Towards and Away oriented pairs in Experiments 5 and 6. Error bars indicate standard error. *p<.05

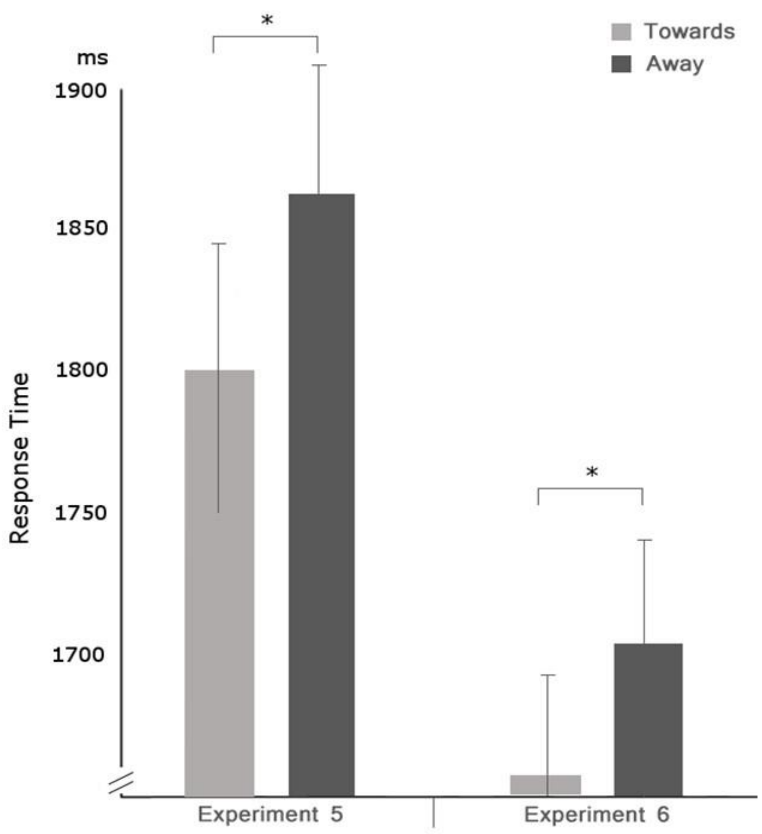


Figure 4.7. Mean response times for Towards and Away oriented pairs in the encoding phase of Experiments 5 and 6. Error bars indicate standard error. *p<.05

Visual longer-term Memory

Binomial tests (.50) confirmed that participants performed above chance in all conditions (all $p<.05$).

A 2x2 mixed ANOVA testing for memory accuracy showed significant main effects for initial Towards or Away orientation of stimuli ($F(1,58)=32.45$, $p<.001$, $\eta_p^2=.359$), color or orientation feature to be recalled ($F(1,58)=48.02$, $p<.001$, $\eta_p^2=.453$) as well as a significant interaction ($F(1,58)=5.70$, $p=.02$, $\eta_p^2=.090$). Posthoc tests revealed that participants asked to remember looking direction were 12.2% more accurate if the originally presented pair was in Towards rather than Away orientation ($t(29)=4.95$, $p<.001$, $d=0.90$). Participants asked to recall clothing color were 5% more accurate if the individuals had previously been shown in Towards orientation ($t(29)=2.87$, $p=.008$, $d=0.52$). See Figure 4.8 for mean accuracies across conditions. Hence recall advantages for Towards stimuli was observed for both orientation and color recall.

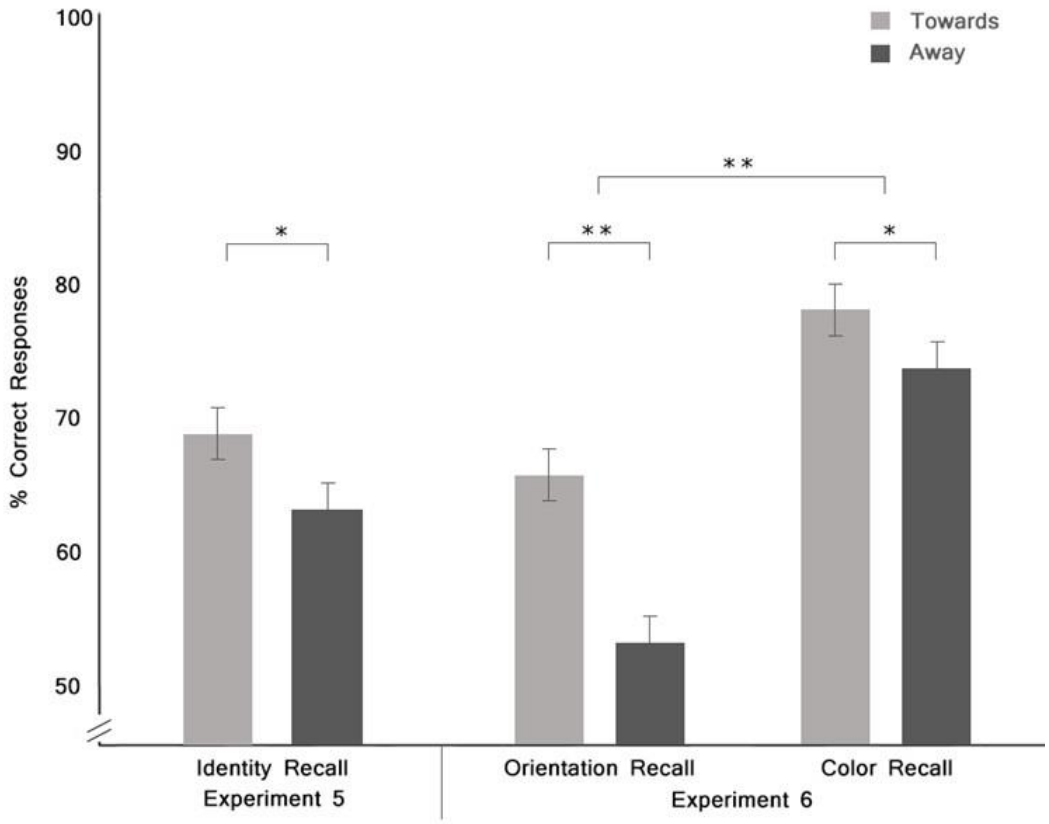


Figure 4.8. Mean retrieval accuracy of participants in all recall conditions. Error bars represent standard error. *p<.05, **p<.001

A 2x2 mixed ANOVA considering only trials in which participants had made the correct response showed response times did not differ depending on initial orientation of stimulus ($F(1,58)=0.51$, $p=.48$) or feature to be recalled ($F(1,58)=1.91$, $p=.172$), but a significant interaction between these variables was found ($F(1,58)=7.28$, $p=.009$, $\eta_p^2=.111$). Posthoc tests based on this interaction revealed that participants were significantly faster to respond to stimuli that had previously been shown in Towards orientation when they were asked to recall looking direction of an individual ($t(29)=2.43$, $p=.022$, $d=0.45$). When asked to recall clothing color there were no significant effects ($t(29)=1.40$, $p=.174$). See Figure 4.9 for response times across conditions.

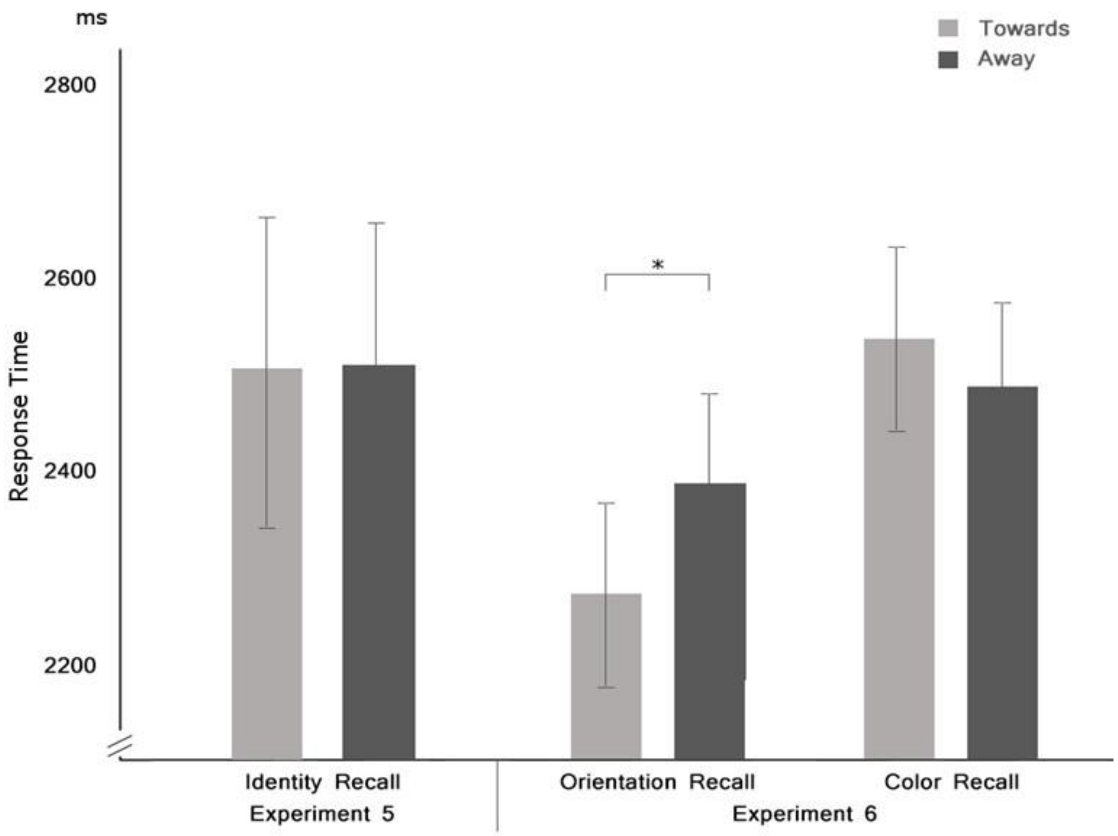


Figure 4.9. Mean response times of participants in all recall conditions. Error bars indicate standard error. *p<.05

Discussion

Memory advantages have again been found for individuals that were socially grouped during encoding. As the stimuli were identical during retrieval between the participants that saw a given stimulus as previously bound and those that saw the stimulus previously as part of a non-facing pair, any explanations on the basis of grouping of the recall stimulus or other low-level factors during retrieval can be excluded.

The prediction for the recall of the direction an individual had been facing was for facilitated retrieval of this socially relevant property when a social interaction between two people was encoded. This prediction was confirmed, where recall of the direction a person had been facing was more accurate when the person had been encoded as a group with another individual in the Towards condition relative to separate individual representations of non-interacting individuals in the Away condition. This increased accuracy of recall was also accompanied by more efficient retrieval processes as time to respond was faster in the Towards condition.

The results regarding the unrelated property of clothing color suggest that even irrelevant properties are also more efficiently retrieved from grouped representations. While these effects appear weaker here than the Social Binding benefit in the direction condition, the slight difference in recall tasks makes a direct comparison unreliable. However, now that an effect of Social Binding on memory accuracy even for irrelevant features has been established, it is possible to design future studies to more directly compare these benefits for a variety of features.

This experiment was carefully designed to avoid asking participants to recall features of one individual that might be confused with the features of the partner. This is to avoid effects of a secondary unitisation process (McLaren & Mackintosh, 2000; Alvarez, 2011) in which features of the dyad members are combined, simplified or averaged, making it harder to then remember individual features or to associate them with the correct dyad member. Such processes have been shown to occur in gestalt grouping (Corbett & Oriet, 2011; Corbett, 2016) and will be investigated in the context of social stimuli in the following experiment.

Experiment 7: Memory for Head-Body Combinations

The previous two experiments show that memory accuracy for previously grouped individuals is increased when the feature to be retrieved for one individual cannot be confused with one of the partner's features. That is, both the identity of the partners who have previously been interacting as well as individual features, such as color and facing direction, are remembered more accurately.

This experiment will now explore potential secondary effects of unitisation (McLaren & Mackintosh, 2000; Alvarez, 2011) of grouped pairs where the features of one individual could be confused with the person they are paired with: One of the underlying assumptions of Social Binding is that grouping of interacting pairs in memory would provide advantages through simplification and grouping of features at a group level. If these features are indeed associated in memory with the group, i.e. with both members, rather than the individual, then associating them with the correct group member afterwards would become more difficult as the individual features cannot be allocated to the correct individual easily after grouping.

This phenomenon has been shown to occur in gestalt grouping with features of multiple objects being remembered at a group level (Corbett & Oriet, 2011) and averaged between the constituent objects, subsequently altering the recalled features more closely towards the group average. Small objects that are part of a group of identical but larger objects, for example, are subsequently remembered as larger than they were during encoding (Corbett, 2016). Considering Experiment 5, in which the identities of interacting individual had to be remembered, no confusion was possible as the memory of the dyad also contained the identity of the members of that dyad. The individual features of those members, however, may be remembered as features of the group rather than features of the individuals. It should therefore be harder for an observer to correctly identify when those features are swapped between group members compared to conditions where the same features are swapped between individuals who are not bound, i.e. those who had not been interacting previously.

In the context of the experimental design used here, this means that when being presented with individuals during recall either with the same features as when they were encoded or with the features of their partner, the observer would be less accurate in distinguishing between these two possibilities if the partners had been encoded as socially bound. Therefore, the hypothesis in this experiment is the opposite of the pattern found in the previous experiments: Memory accuracy will be decreased for individuals that are part of interacting pairs.

Methods

Participants

40 participants (32 female, 8 male) took part in the experiment in exchange for course credit of payment.

Materials

The same material as in experiment 5 were used. For each stimulus person, an alternative image was created using Adobe Photoshop with the same head as that person but the body of their partner, see Figure 4.10 for an example.

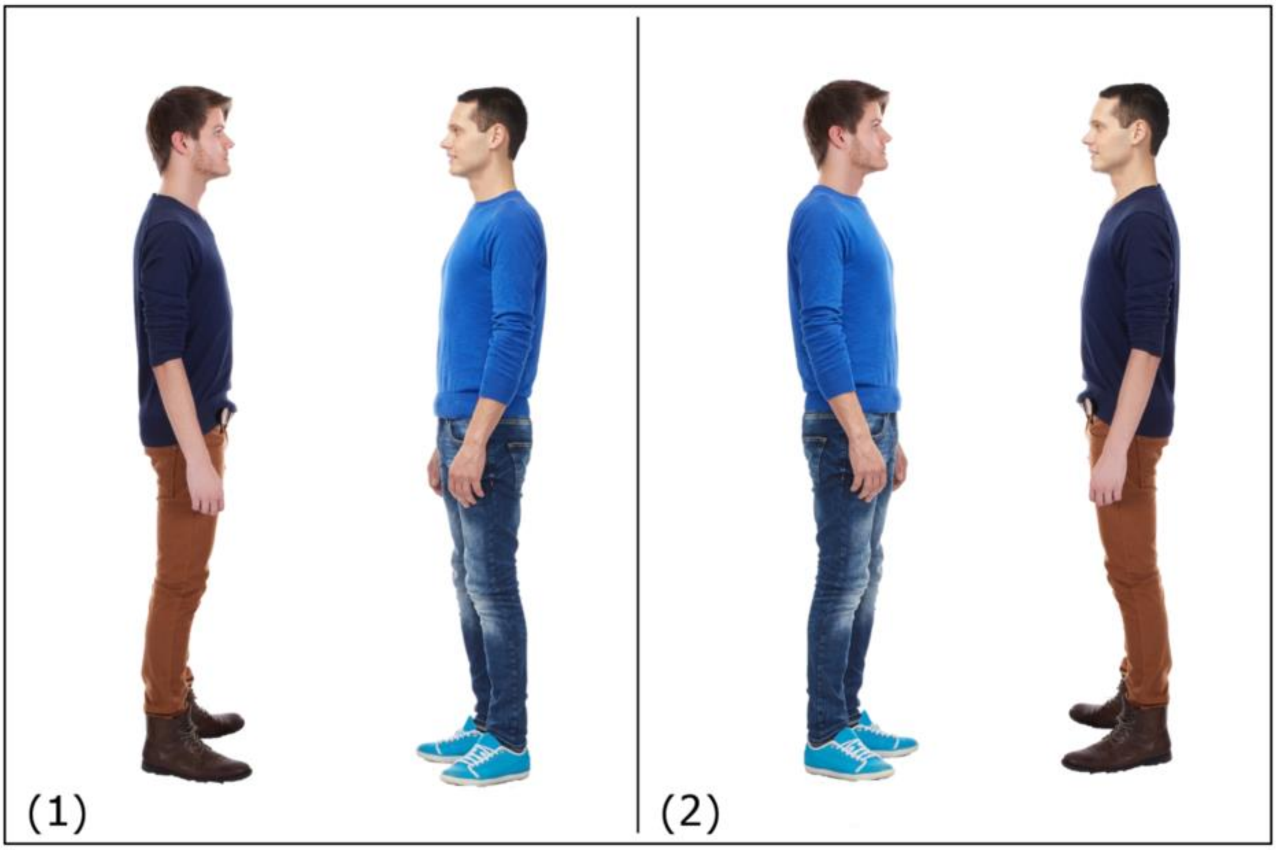


Figure 4.10. A facing pair consisting of two of the original stimuli (1) as well as two of the stimuli with new head-body combinations (2).

Design

Spatial Errors and response times were analysed as in experiments 5 and 6. A within-subjects t-test was used to investigate differences in Accuracy and Response Time between individuals that were previously shown as members of a facing or non-facing pair.

Procedure

The procedure was identical to the one in Experiments 5 and 6 with the recall instructions to indicate whether the individual had been seen in the spatial judgment task with the same or a different body. Half of the person stimuli in the encoding phase were original images, the other half were newly created head-body combinations. This was done in order to avoid systemic effects of slight mismatches in the new head-body combinations, which might influence participants' response as to whether the body belongs to the head shown. This was counterbalanced between participants.

For the memory task participants were shown the individuals they had seen before again, half of which were presented as seen in the encoding phase with the other half presented with the body of their partner. Participants were asked to indicate through key press whether the stimulus shown was the same as in the first stage of the experiment or whether it was someone with another person's body. Possible retrieval cues are shown in Figure 4.11.

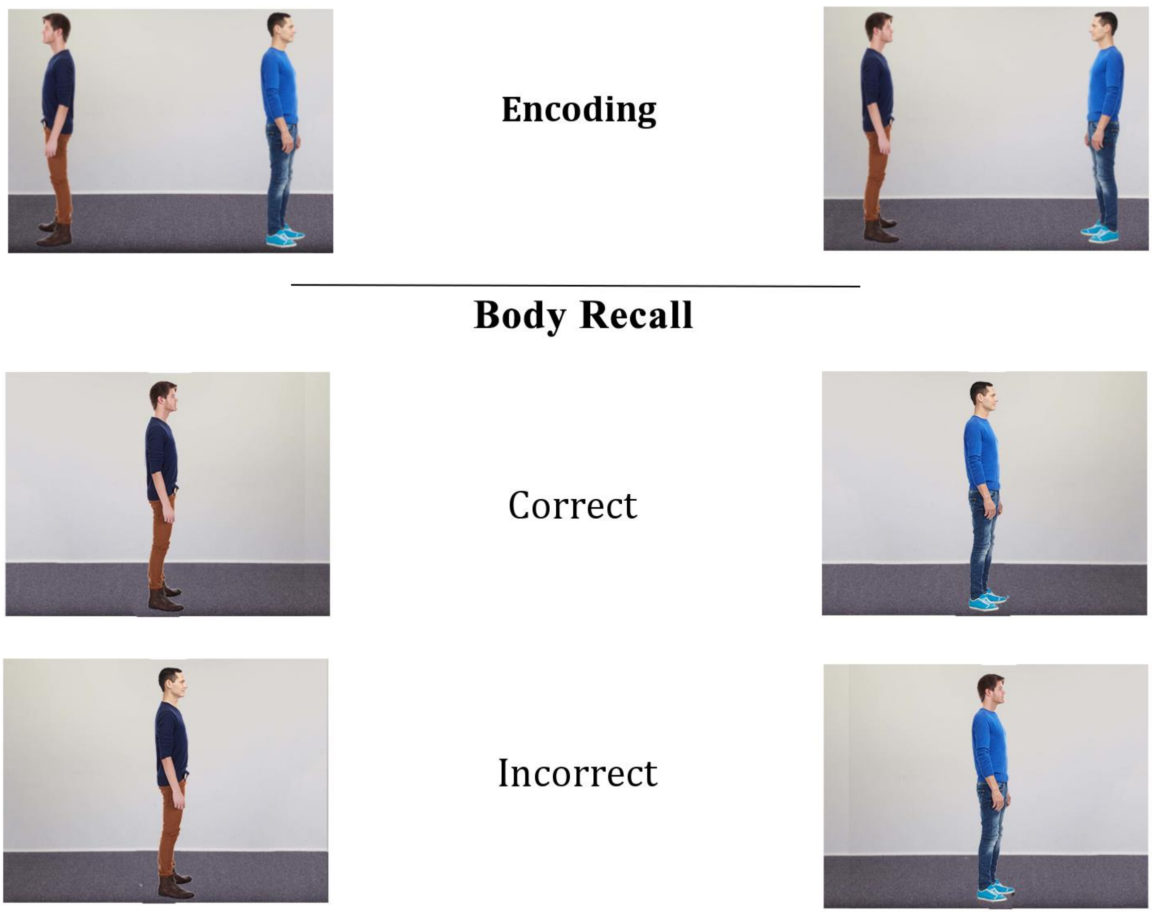


Figure 4.11. An example of an encoded pair in Away (left) and Towards (right) orientation with the corresponding possible retrieval prompts.

Results

Spatial Judgments

Within-subject t-tests did again show a significant difference in Spatial Error between the different orientations here ($t(39)=2.28$, $p=.028$, $d=0.36$) - see Figure 4.12. Also, as can be seen in Figure 4.13, participants were - similarly to all the previous experiments - faster in responding to facing pairs as opposed to non-facing pairs ($t(39)=4.72$, $p<.001$, $d=0.78$).

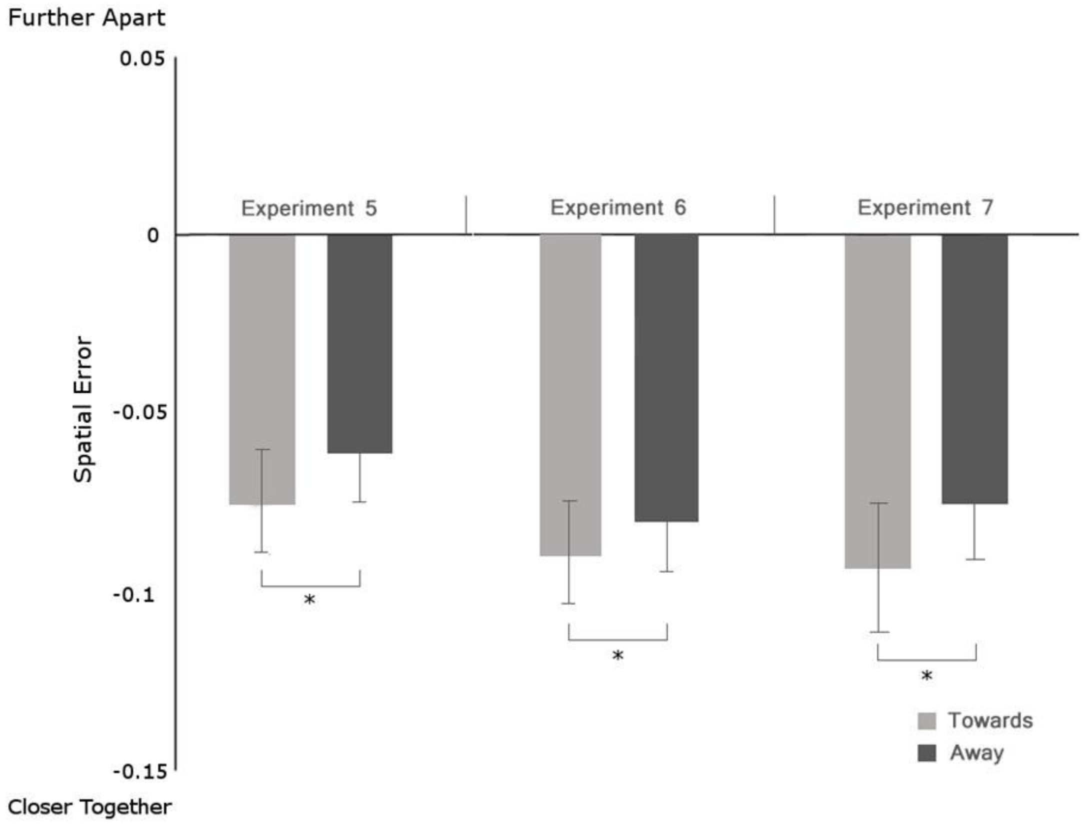


Figure 4.12. Mean spatial error for Towards and Away oriented pairs in Experiments 5, 6 and 7. Error bars indicate standard error. *p<.05

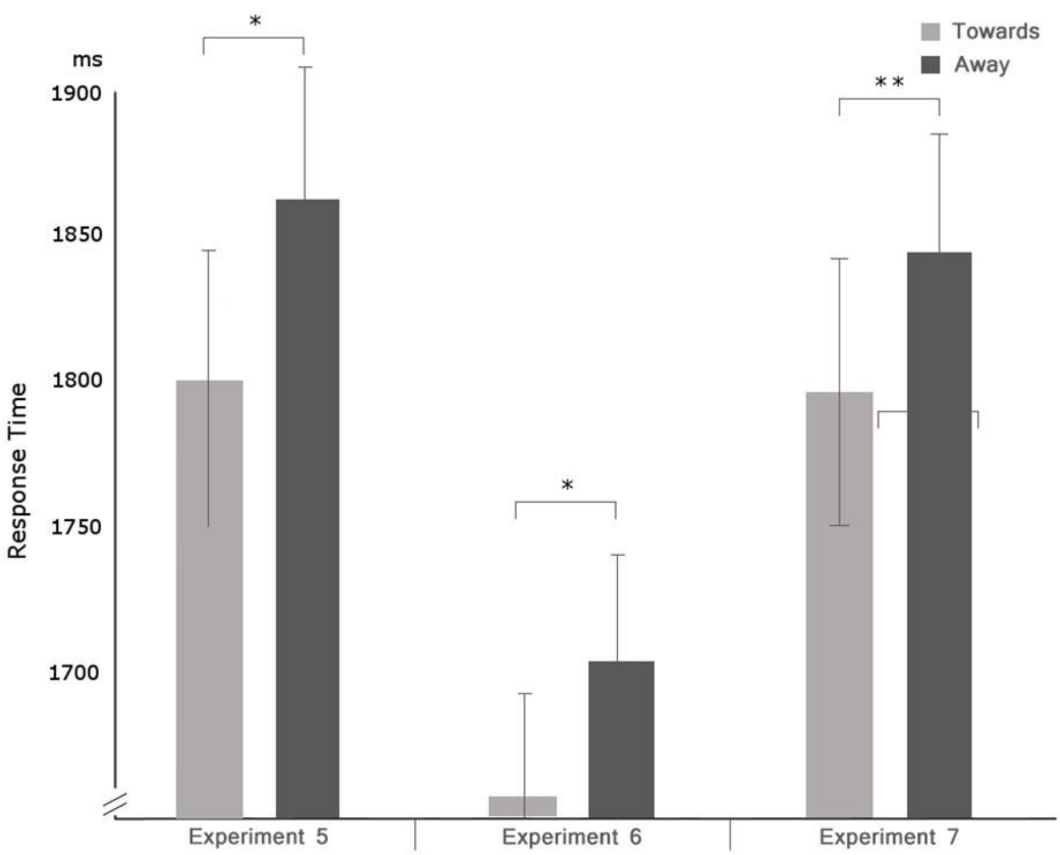


Figure 4.13. Mean response times for Towards and Away oriented pairs in the encoding phase of Experiments 5, 6 and 7. Error bars indicate standard error. *p<.05, **p<.001

Visual longer-term Memory

Performance was above average in all conditions, as confirmed by binomial tests (.50, p<.05). Participants were 6% less correct when stimuli had previously been part of facing pairs. A pairwise comparison revealed this difference to be significant ($t(39)=3.13$, $p=.003$, $d=0.50$). There was, however, no significant difference in response times ($t(39)=0.22$, $p=.830$). See Figures 4.14 and 4.15 for mean performance in all conditions.

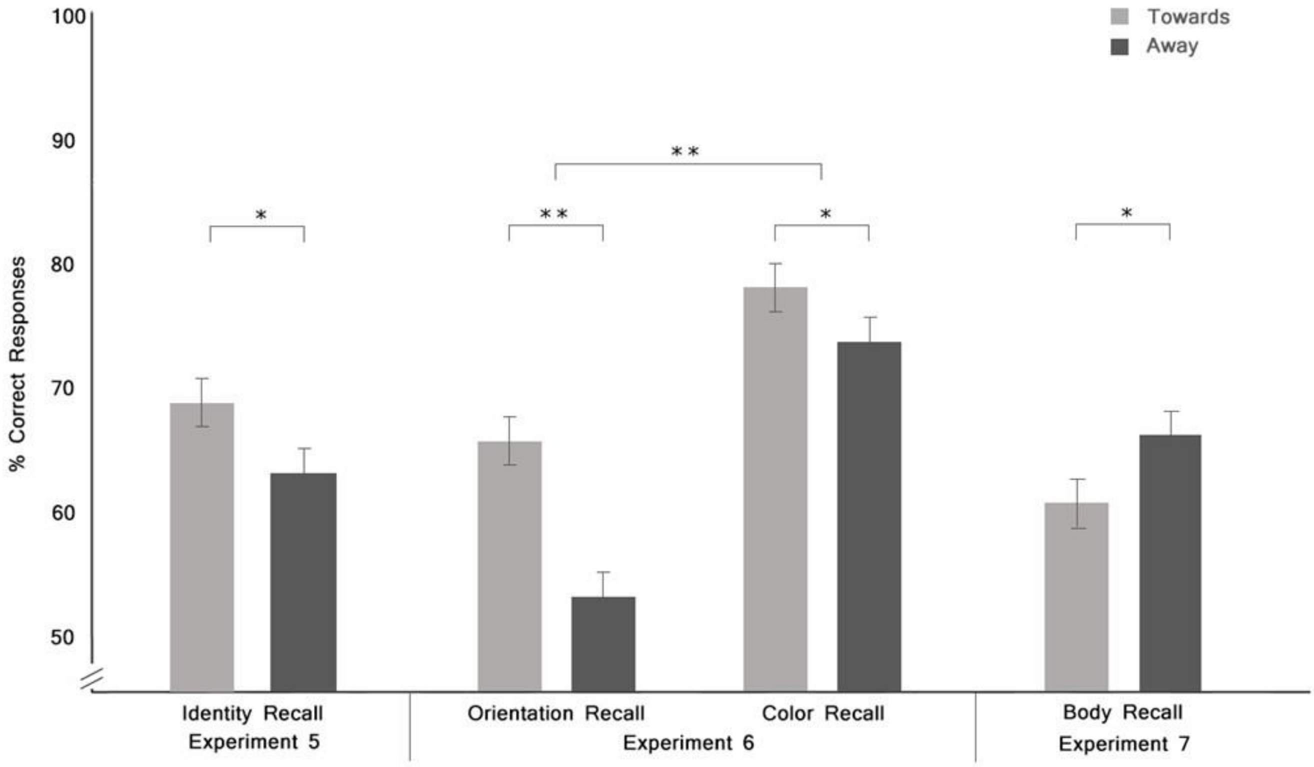


Figure 4.14. Mean retrieval accuracy of participants in all recall conditions. Error bars represent standard error. *p<.05, **p<.001

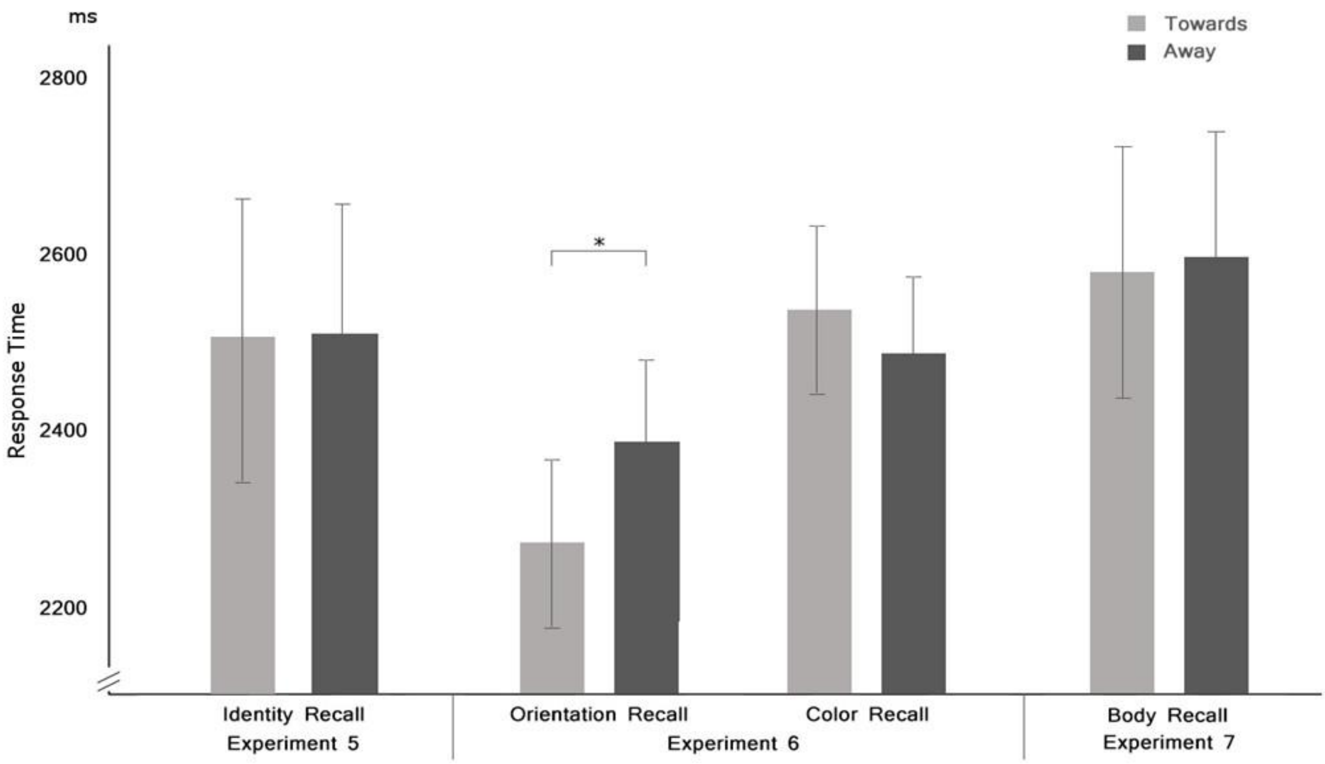


Figure 4.15. Mean response times of participants in all recall conditions. Error bars indicate standard error. *p<.05

Discussion

This experiment found results with the opposite pattern of the previous experiments: Memory accuracy during recall was reduced by implied interaction during encoding of the towards facing individuals. This supports the Social Binding model as it implies an association in memory of the partners and encoding of features at a group level, showing that the binding processes studied here are involving processes similar to gestalt grouping (Alvarez, 2011; Corbett & Oriet, 2011).

Importantly, the features investigated here were misapplied more often in members of facing dyads but couldn't be averaged between them as has been found to occur in gestalt grouping (Im & Chong, 2014; Corbett, 2016). This opens up the possibility for future experiments that investigate more closely the hypothesis that certain features of individuals are distorted by surrounding individuals or by their perceived group membership.

Chapter 4 - General Discussion

The main motivation for the experiments presented in this chapter was the investigation of the previously observed social grouping effects on recall. It was predicted that when people were observed to be interacting, they will be bound into memory as a single event. Hence when later retrieving information from a single event file created by grouping social interactions (Towards condition), this will facilitate retrieval in comparison to conditions where each person is encoded as a separate event (Away condition) in some circumstances, but impair retrieval in other conditions..

The experiments examined retrieval of various kinds of information: Retrieval of pairs as a whole (pair identity) as well as individual features that were considered to be a property of the social interaction (direction of gaze) and those that were irrelevant to the social interaction (color of clothes). This was followed by an investigation into features that had the potential to be confused between the partners (body recall). An overview can be found in Figure 4.17. Memory accuracy was consistently and significantly increased for members of interacting pairs for the first three features, whereas this pattern was, as predicted, reversed in the last experiment.

In contrast, the response time effects in these memory retrieval studies are less clear. Although significant effects were observed when recalling person orientation, no effects were detected when recalling color of clothing, person identity or body-head composition. Hence speed of memory retrieval may not be such a sensitive measure as accuracy of recall. Although of note, speed was not emphasised as a response requirement, hence future studies requiring recall decisions to be made as fast as possible might detect effects in response time.

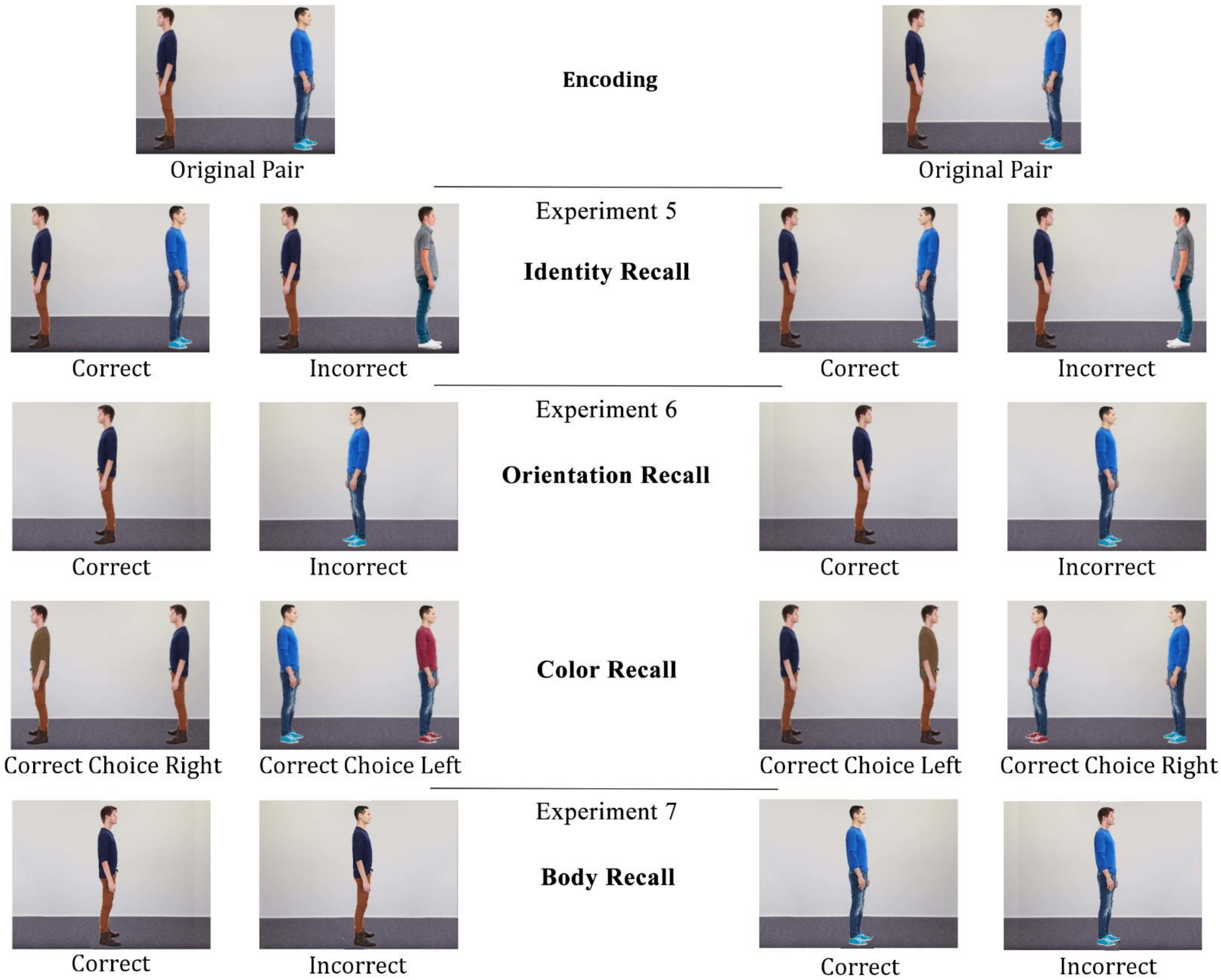


Figure 4.17. An example of an encoded pair in Away (left) and Towards (right) orientation with the corresponding possible retrieval prompts in Experiments 5, 6 and 7.

The encoding stage of these memory effects also provided ample opportunity to test the robustness of spatial distortion and response time effects. Response time advantages of facing pairs in spatial judgments have been replicated throughout and further support the results found in Chapter 3. Spatial errors were also made with the same pattern as in the previous studies.

The advantage of the experimental designs used here is the complete absence of any visual differences in recall prompts between conditions. This excludes the possibility of low-level confounds systematically influencing the findings. The combination of spatial judgments and visual memory tests is especially interesting for potential future studies as it provides a rich amount of data on the various stages of Social Binding from working memory retrieval within a second, to longer-term incidental retrieval over minutes.

Overall the results in this Chapter support the hypothesis that interacting individuals are bound together and encoded into memory as a group rather than individually, and retrieval from such grouped representations is more efficient, in agreement with previously observed effects of perceptual grouping of objects according to gestalt principles on working memory (Woodman et al, 2003). Indeed, it appears that a range of properties are more efficiently encoded into memory during social interactions, such as the identity of a person, the orientation the person is facing, and the color of their clothing. This efficiency has been shown in certain circumstances to lead to less accurate memory performance when the combined representation of the group leads to less individualized representations of each person, as in the body-swap task. These properties were not explicitly processed in the initial spatial memory task and subsequent requirement for recall was not expected by participants, hence supporting the notion that such incidental encoding is automatic when perceiving social interactions.

Chapter 5:

Boundaries and Future Research Areas

The previous chapters have answered the central question of this thesis by establishing Social Binding as a phenomenon with effects spanning early perception in visual search, spatial judgments in short-term working memory and incidental encoding and retrieval from longer-term memory. While this concludes the aim of providing an overarching theory and experimental paradigms to facilitate future research into Social Binding, it would be amiss not to provide further studies examining possible boundary conditions of these effects, and provide an outlook and direction for future research questions. To this end, a last series of basic exploratory experiments will provide an initial examination of various boundary conditions and possible further research avenues. Inspired by both the previous experiments as well as existing literature on the topic of motivated distance perception (Balcetis, 2015; Schnall 2017), this chapter is concerned with manipulations beyond the basic binary manipulation of whether two people are viewed to be potentially interacting (towards) or not (away condition)..

The social binding processes demonstrated thus far can be considered to be basic automatic processes that perhaps provide the input to higher level processes. That is, throughout the experiments participants are never required to explicitly consider the spatial relationship between two people, they simply have to detect specific targets in visual search, or recall the relative spatial location of a person at a later time. There are two further issues to consider regarding these initial binding processes: The first concerns whether the distortions of spatial memory caused by Social Binding are specific to these processes, or can be detected in other interactions that do not depict human social interaction. To investigate this, Experiment 8a and 8b will manipulate the threat level of a non-human stimulus to examine whether this can also produce distortions of space. If no such effects are detected, it would support the idea that it is specifically human social interactions in allocentric frames of reference that are given preferential processing.

The second issue concerns whether the initial computations of social binding interact with later processes where more subtle computations might take place. In the theoretical framework of Social Binding this would constitute a secondary 'follow-up' process that, after establishing an interaction and therefore grouping individuals together, would evaluate the group further and potentially incorporate expectations, biases or goals of the observer. As this level of processing would naturally happen much later than the initial binding, it is unlikely to find evidence of it in processes as early as visual search. Therefore, the following experiments will test for spatial distortion as well as response time differences based on higher-level computations in short-term visual memory.

In sum, Experiments 8a and 8b will initially investigate whether non-human threat stimuli can influence recall of spatial location in an allocentric frame. Such effects have been noted in egocentric frames of reference (Cole et al., 2012; Balcetis, 2015) , but may not be observed in the new experimental paradigm described in this thesis. Experiments 9a and 9b then goes on to manipulate abstract knowledge about the quality of the relationship where spatial recall is compared for pairs of individuals who are described as close friend compared to those described as strangers who have never met. Finally, Experiments 10a and 10b will employ human-like but noticeably artificial avatar representations of individuals to examine whether the previously found spatial distortion and response time effects extend to these artificial stimuli as well. As before, but especially important here because this is an exploration of variables quite different to those involved in the previous chapters, all findings will be replicated twice in order to reduce the chance of Type I and II errors.

However, it is important to note that the purpose of these final experiments is to provide a first, tentative glance at these manipulations and how they might be approached. It is not possible for any of these experiments to exhaustively investigate any of these factors. Rather, they are intended to test how the presented paradigms can be extended further. The results will also give an initial idea as to the validity of these research questions.

Experiment 8a: Human-Animal Interactions I

In the first exploratory study, binding effects on the basis of threatening interactions will be investigated. A wide range of studies in the realm of egocentric distance perception have reported findings of under- or overestimated distances resulting from perceived threat of the target towards which the distance is judged (e.g. Cole et al., 2012; for an overview see Balcetis, 2015). That is, when participants directly judge the distance of a stimulus to themselves, this judgment is influenced by whether the stimulus is a fear evoking threat. These results from egocentric frames of reference make an investigation into similar effects in allocentric space worthwhile, as similar embodied or predictive mechanisms might also influence the distance judgments between a person and a threatening partner, animal or object.

As Social Binding effects have already been shown between two human partners, it would seem most logical to manipulate the implied threat-level between two persons. However, manipulating perceived threat in a human figure would involve either abstract information explicitly given to the participant or a manipulation of the body posture to a more dynamic representation that implies aggressive action. While the efficacy of abstract information has not been investigated yet and cannot be assumed, using highly dynamic body postures may introduce confounds on the basis of representational momentum similar to those already discussed that would produce effects not on the basis of implied threat but because of a forward prediction of the depicted movement (e.g., Brehaut & Tipper, 1996).

The existing literature has shown animals to be highly salient stimuli that can reliably elicit threat responses (Cole et al., 2012; Purkis & Lipp, 2009). Pairing threatening as well as non-threatening animals with humans therefore provides stimuli that are clearly recognised as either dangerous or benign interactions by most participants without the need for explicit instructions. To this end, and in line with the previous literature (e.g., Purkis & Lipp, 2009), snakes and spiders represented dangerous animals while pictures of young puppies and kittens were chosen for the non-threatening stimuli. Participant's ratings as to the perceived threat from each animal further accounted for potential individual differences.

Method

Participants

36 University of York students (31 female, 5 male) took part in the experiment for course credit or payment. 6 participants were excluded after completing the experiment as they rated none of the presented animals as threatening (see procedure).

Materials

For the animal stimuli in this experiment, two threatening animals (snake, spider) and two non-threatening animals (dog, cat) were chosen and can be seen in Figure 5.1. In order to equalize the height of human and animal stimuli, one male and one female human model were photographed sitting cross-legged with their hands on the ground. This also produced a display in which the depicted person cannot simply step back from the animal to resolve the potentially threatening situation. Due to the inability to easily escape, the perceived threat level should be higher, which in turn makes spatial distortions more likely (e.g. Cesario et al., 2010; Balcetis, 2015).

Additionally, because the animals are not at eye level with the person, varying the distance between animal and human would take the animal out of the line of sight of the person. To circumvent this problem, pictures were taken of the models in the same sitting position but with 20 different head rotations. The appropriate head tilt can then be chosen based on the distance between animal and human so that the individual was always looking at the animal. See Figure 5.2 for examples. This, of course, would also mean that if the human dyad member reappeared and the animal's previous location was supposed to be indicated, the human would look at the correct orientation, thereby influencing the participant's choice of response location. Therefore, the re-appearing human stimulus during the animal location recall task always looked straight ahead. The same background was used as in Experiments 3 and 4 and stimuli were superimposed on it as can be seen in Figure 5.2.

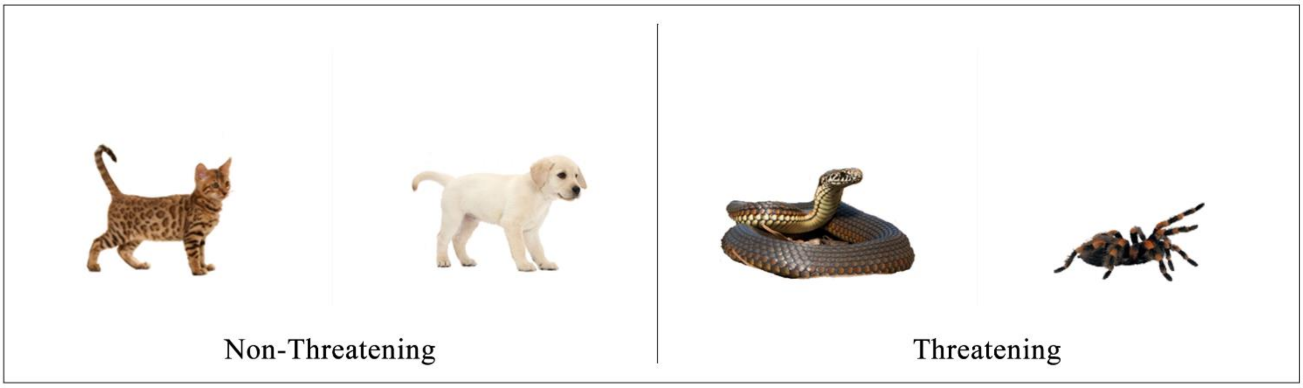


Figure 5.1. Non-Threatening (left) and threatening (right) stimuli used in this experiment.

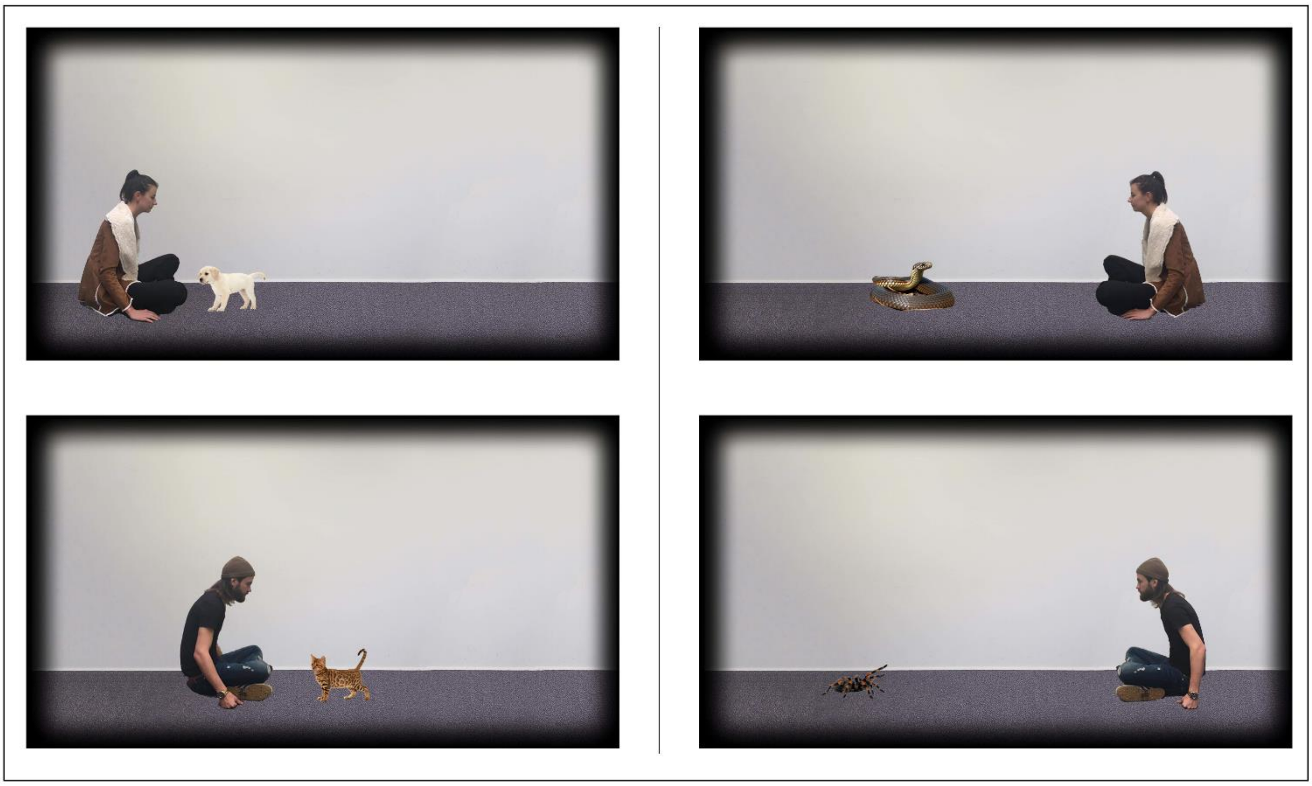


Figure 5.2. Human animal pairs including both female (top) and male (bottom) models with non-threatening (left) and threatening (right) animals. Note that distance is varied without the animal leaving line-of-sight of the human partner.

Design

A pairwise comparison was used to analyse the data for effects on Spatial Error as well as Response Times resulting from Affect (threatening / non-threatening) of the stimulus.

Procedure

The procedure was identical to the spatial distortion experiments in Chapters 3 and 4 where displays were viewed for 3 second, then after a 1 second interval, the location of one of the stimuli (animal) had to be recalled with a pointing response on the touch screen. The only difference from previous studies was a new stage added to the end of the experiment during which participants were shown each animal again and were asked to rate how threatening they felt the animal is on a Likert scale between 1 and 5. For each participant, trials involving animals that were rated 1-2 were classified as non-threatening stimulus trials (exclusively dogs and cats) whereas trials involving animals scored as 4-5 (exclusively spiders and snakes) were classed as involving threatening stimuli. Animals rated as 3 (medium threatening) were not considered in the further analyses. 6 participants did not rate any animal above 3 and were therefore excluded from further analysis. Trials involving Spatial Error more than 3 standard deviations from the mean and Response Times of less than 500ms or more than 5000ms were excluded from further analysis (<3% of trials).

Results

A paired t-test showed no significant effect of Threat on either Spatial Error ($t(29)=0.003$, $p=.998$) or Response Times ($t(29)=0.036$, $p=.971$). See Figure 5.3 as well as Appendix A for means and standard deviations.

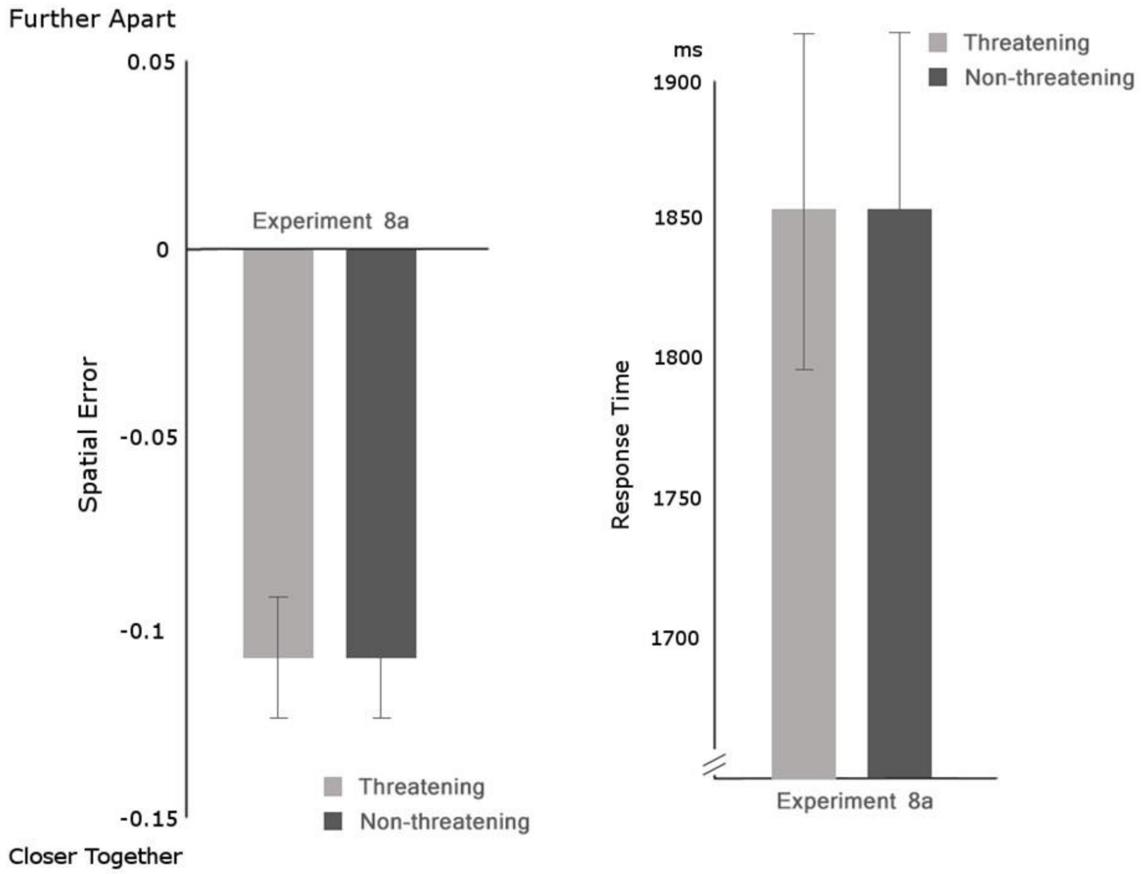


Figure 5.3. Mean spatial error (left panel) and response times (right panel) for all conditions of Experiment 8a. Error bars represent standard error. **p*<.05

Discussion

The results from this study are somewhat surprising. No effects consistent with post-binding processes involving perceived threat of a stimulus were found. This contrasts with prior work showing such effects in egocentric frames of reference. Therefore a further experiment is required before any conclusions can be drawn from such a null result. It is possible that even though participants had the abstract knowledge of the threat presented by each animal, the display itself lacked emotional salience. This experiment also cannot present any evidence as to whether humans and animals are grouped together at all depending on whether they are interacting or not.

The second part of this experiment, therefore will add an orientation condition in which animals and humans are presented facing and non-facing, as well as use short video clips of spiders and snakes engaging in aggressive behaviour before the corresponding trials in order to reinforce the implied danger of the displayed interaction.

Experiment 8b: Human-Animal Interactions II

Method

Participants

39 University of York students (37 female, 2 male) took part in the experiment. 9 did not rate any animals as threatening and were therefore excluded from further analysis.

Materials

The same materials as in Experiment 8a were used, but 6 additional video clips of 3 second length were generated, showing 3 spiders and 3 snakes engaging in threatening behaviour. As can be seen in Figure 5.4, human-animal pairs were shown in both Towards and Away orientations.

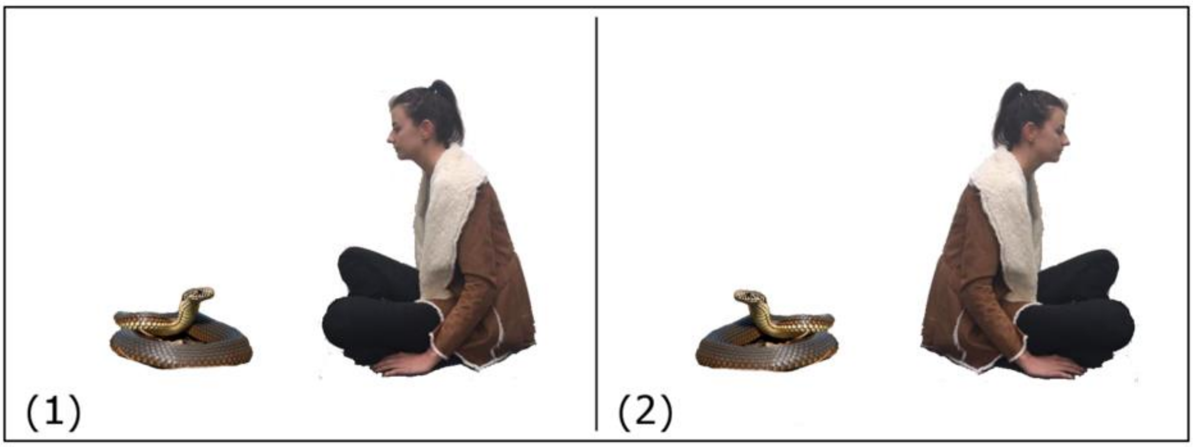


Figure 5.4. An example of a human-animal pair in both Towards (1) and Away (2) orientation.

Design & Procedure

A within-subjects design investigates effects of Orientation (Towards / Away) and Affect (Threatening / Non-threatening) on Spatial Error and Response Times. The procedure was otherwise the same as Experiment 8a except for the video clips, one of which (randomly chosen) was shown before a third of the corresponding trials involving threatening stimuli. As before, trials involving Spatial Error more than 3 standard deviations from the mean, Response Times of less than 500ms or more than 5000ms, and those where the target stimulus was placed on the wrong side of the cue stimulus, were excluded from further analysis as well (<2.5% of trials).

Results

As can be seen in Figure 5.5, a mixed ANOVA showed a significant effect of Towards vs Away orientation on Spatial Error ($F(1,29)=14.27$, $p=.001$, $\eta_p^2=.330$) replicating previous findings of recall of reduced distance, when there is an interaction between a person and animal, in this case. However there is no effect of the threatening nature of the animal during recall of its location ($F(1,29)=1.06$, $p=.313$) and no interaction ($F(1,29)=1.50$, $p=.231$).

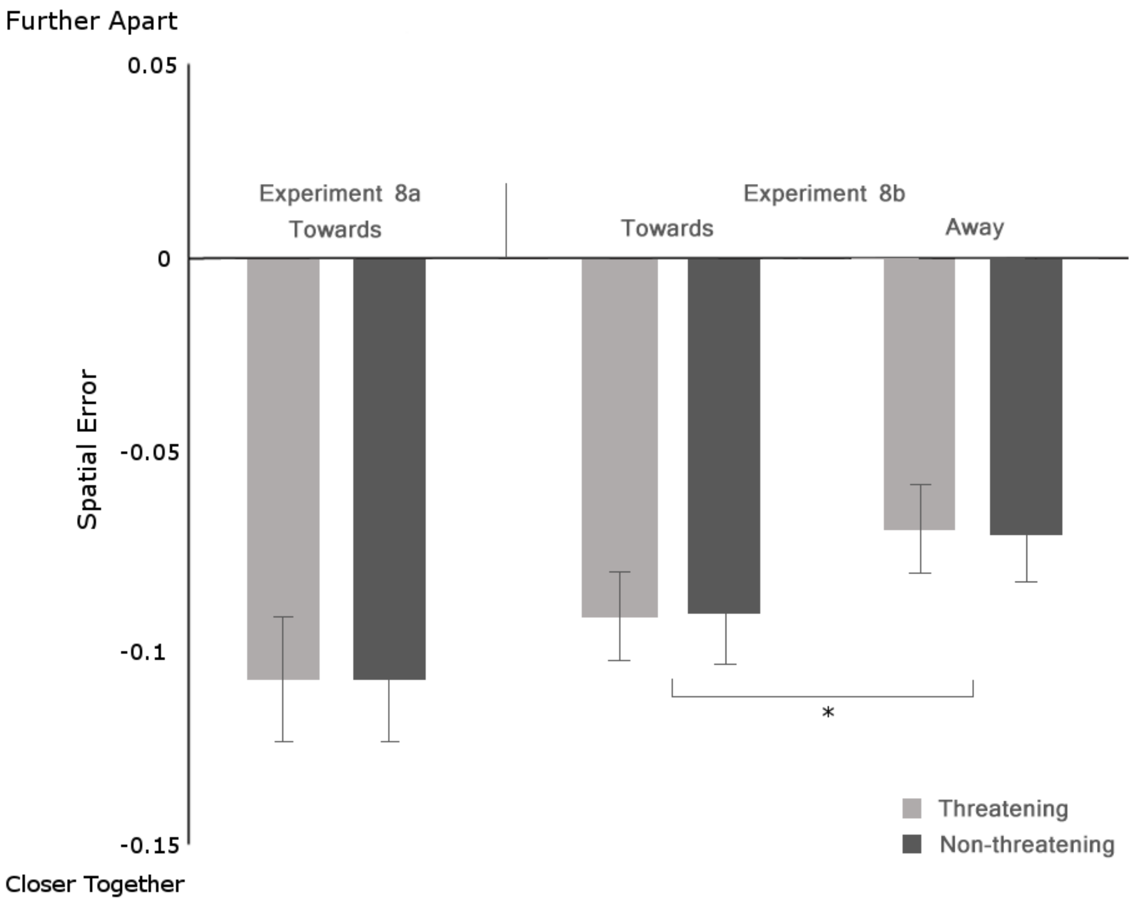


Figure 5.5. Mean spatial error for Experiments 8a (left panel) and 8b (right panel) for all conditions. Error bars represent standard error. *p<.05

Similarly, Response Times were significantly faster when recalling the location of the animal in the Towards condition, again replicating previous findings ($F(1,29)=5.70$, $p=.024$, $\eta_p^2=.164$) but speed of recall was not influenced by the threat of the animal ($F(1,29)=2.29$, $p=.141$). There was also no significant interaction here ($F(1,29)=0.82$, $p=.373$). Details can be seen in Figure 5.6.

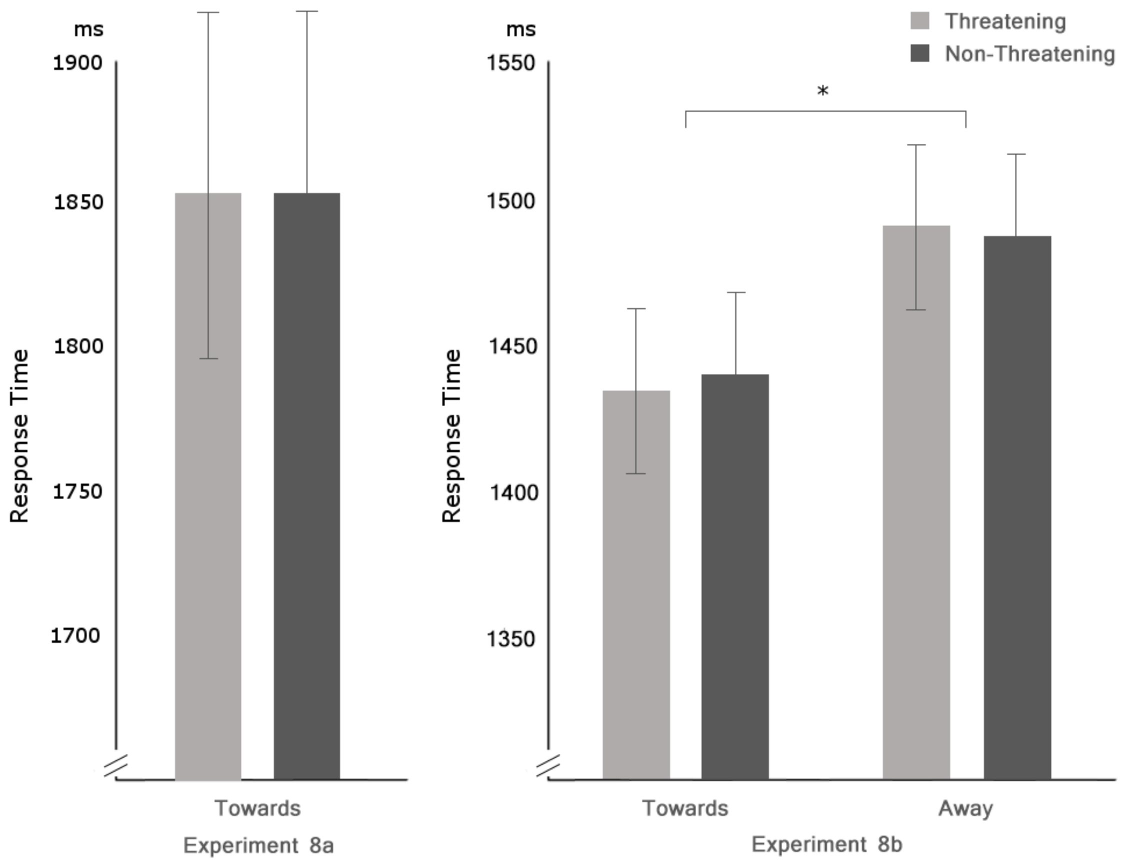


Figure 5.6. Mean response times for Experiments 8a (left) and 8b (right). Error bars indicate standard error. *p<.05

Discussion

Distance effects of Towards vs Away have been observed in a series of studies in Chapters 3 and 4, and have again been confirmed in this experiment. That is, the location of an animal is recalled as closer to a person if the person is engaged with and looking directly at the animal. However, as in Experiment 8a, the potential fear evoking threat of the animal has no effect on the recall of spatial location. While it seems that information regarding the threat of a situation is not integrated into the combined memory engram in a way that would alter either spatial judgments or response speed, it is worth pointing out unlikely but still possible scenarios in which such effects could exist but would not be shown here:

Approach and avoidance reactions are thought to facilitate spatial distortions in egocentric judgments but are only vaguely defined (Balcetis, 2015). If such motivations influence allocentric distance perception it is possible that participants interpreted the displayed interaction as an approach interaction in both the cases involving threatening and non-threatening stimuli, i.e. the fight response in the threatening situation and friendly interaction in the non-threatening stimuli both lead to equally underestimated distances. There is, however, no evidence for this and it is questionable whether such non-specific distortion effects could still be considered secondary effects or whether they simply would present pure binding effects on the basis of a perceived interaction.

More interesting are the results pertaining to implied (non-)interaction through changes in orientation. This experiment has provided evidence in support of Social Binding between humans and animals. Seeing that the theory of Social Binding requires interactions but not higher thought processes on the side of the observed actors, this is not surprising. But it does open up more interesting questions for the future: All the animals presented here are unquestionably alive with their own agency and therefore a human-animal interaction is clearly present. But it is not clear whether there is a lower limit in terms of a minimum complexity and predictability of an animal to be perceived to be interacting. On the other hand, it is also an open question whether animate or anthropomorphised objects would be bound with a human figure. This question bridges Social Binding and initial results of binding due to causality in the absence of conscious agents (e.g. Buehner & Humphreys, 2009). As a word of caution, it is worth noting that the animal stimuli here are far more elongated horizontally than any of the human stimuli that have been used in the previous chapters. It is therefore possible that the spatial difference between head location and center of the body of these animals caused inward biases in facing pairs beyond what could be accounted for with the pre-test calibration and therefore the present effects have to be viewed with caution.

Whether other studies could rule out possible confounds and detect effects of threat on spatial memory in an allocentric frame-of-reference remains an open question. However, the current results do indeed support previous work that has examined both egocentric and allocentric information processing when observing human actions. For example, Bach, Fenton-Adams & Tipper (2014), demonstrated that when observing an individual occasionally grasp a pain evoking object, only when this was viewed from an egocentric perspective were object and action information producing negative affect combined. Similarly, Brattan et al. (2016) demonstrated that forward modelling of action states was significantly more accurate when observing actions from an egocentric rather than an allocentric perspective.

Experiment 9a: Background Knowledge of Interacting Partners I

After showing that situational threat is not processed in a way that would further influence the initial Social Binding effects, it is worth investigating other forms of emotional information about the relationship between individuals. Research in motivated egocentric distance perception (Balcetis, 2015) has shown that friendly, desirable or threatening others are in certain contexts perceived to be closer to a participant than neutral individuals (e.g. Thomas et al., 2014; for a review see Xiao et al., 2016). While these effects seem to be mostly dependent on the goals and state of the observer (Knowles et al., 2013), it is possible that similar processes might take place in allocentric representations when observing the interaction between two other people.

Therefore, as stimuli with both positive and negative affect have been shown to elicit approach reactions and therefore underestimated egocentric distances, this experiment compares spatial location recall after viewing pairs of people who are described as close friends ("friends" condition) and pairs who do not know each other, having never met before ("strangers" condition). This manipulation not only alters the quality of the relationship but by inference also the likely intensity of interactions. As the focus here is to manipulate only abstract knowledge, the displays did not differ in any physical way between conditions. Instead, participants were presented two pairs as being friends and told that the pairs did not know each other, i.e. two members from different pairs were strangers. Participants received reminders about the relationship status before trials. The prediction for this experiment was that when recalling the location of an individual from the friends pairing, this would be closer than an individual from the strangers pairing.

Methods

Participants

30 students from the University of York took part in the experiment in exchange for course credit or payment.

Materials

The two dyads from the experiments in Chapter 3 were used as stimuli here and superimposed - always in facing orientation - on the same background as with the previous experiments. Two full-screen introduction slides were generated for each dyad, showing the pair facing each other on the left and a short paragraph regarding their relationship, introducing them as Friends - see Table 5.1. Additionally, a reminder slide with a smiling face and the word “Friends” (see Figure 5.7) and one with a neutral face and the word “Strangers” were generated.

Table 5.1. Introductory paragraphs for friendly and neutral pairs.

Relationship	**Introduction**
Pair 1	These are James and Marc. They are both studying physics and have known each other for 3 years. They visit the same lectures and are close friends.
Pair 2	These are John and Andrew. They are both studying economics and visit the same lectures. They have known each other since the beginning of term but have become good friends.

Design & Procedure

Pairwise comparisons were used to compare Spatial Errors and Response Times between Relationship conditions (Friends / Strangers). The procedure was identical to Experiments 3 and 4 with the exception that participants read one introduction slide of each friendly pair in the beginning. Half of all trials involved one of these pairs, the other half presented members of two different pairs, i.e. strangers. Individuals in each pair as well as which individuals were paired together was counterbalanced between participants. Participants were presented with a reminder slide corresponding to the following display for 1000ms before each trial. Trials with Response Times below 500ms, above 5000ms or Spatial Errors more than three standard deviations from the mean were discarded (<2%).

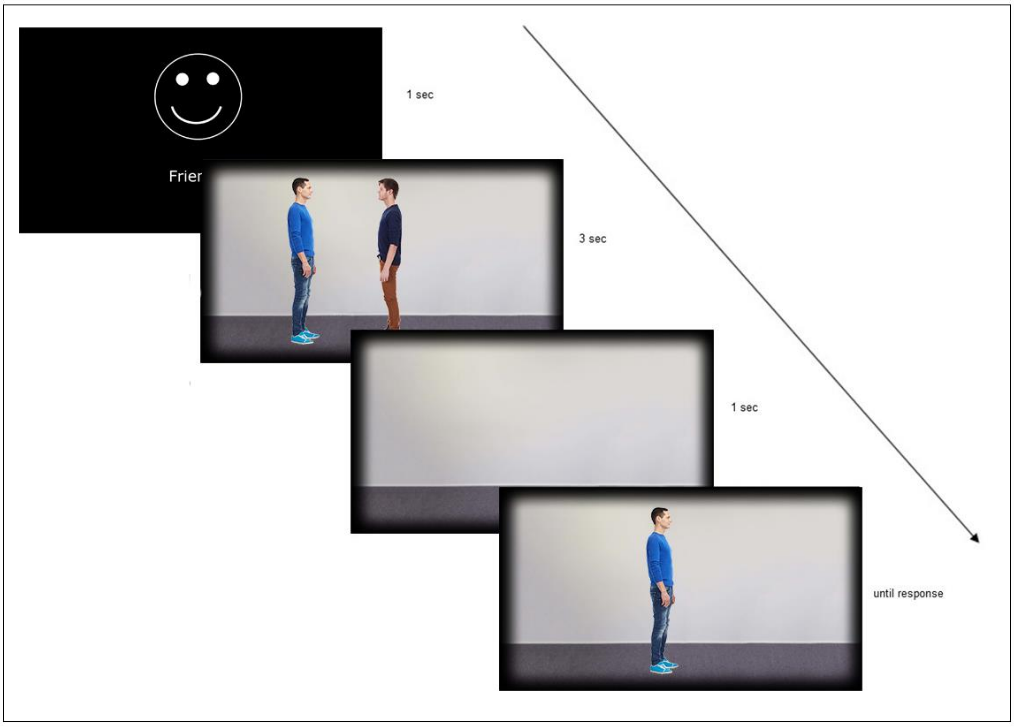


Figure 5.7. Procedure of a Towards oriented dyad with a reappearance of the left partner. A reminder slide regarding the relationship of each dyad was shown before each trial.

Results

Paired t-tests showed that the primed relationship information did not have any significant effects on either Spatial Error (*t*(29)=0.44, *p*=.661) or Response Times (*t*(29)=0.36, *p*=.724) - see Figure 5.8.

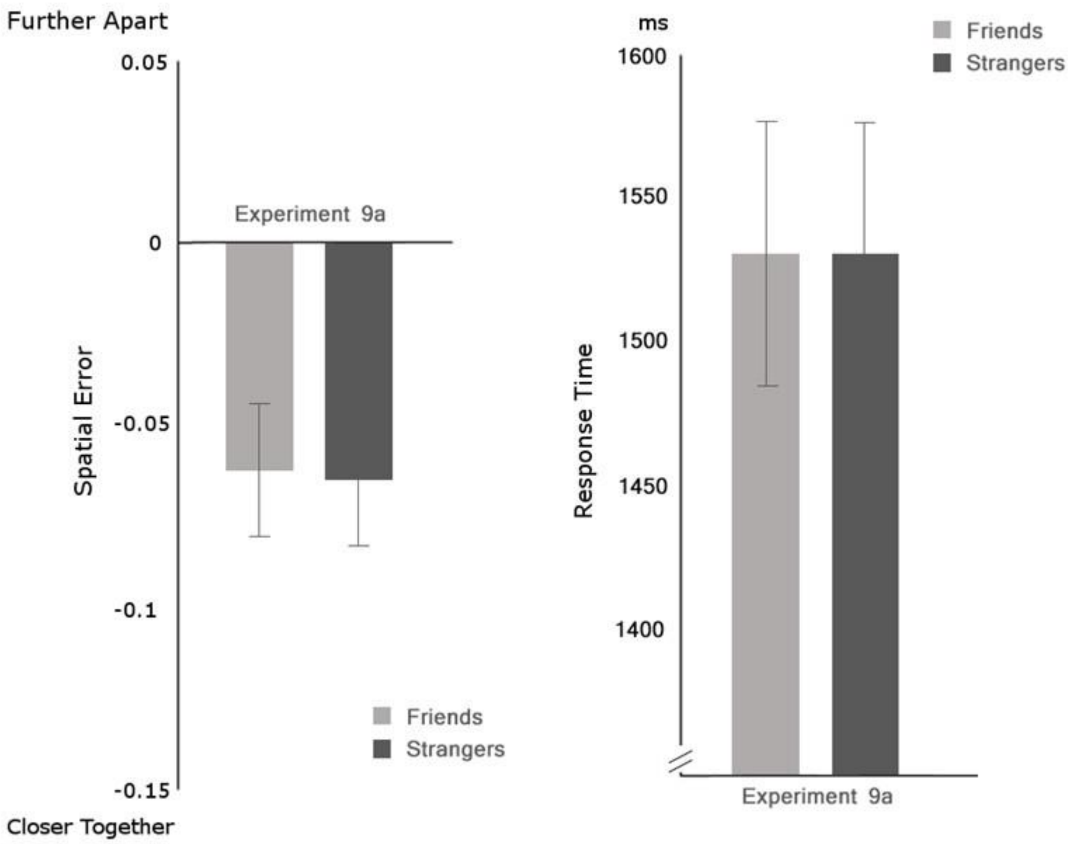


Figure 5.8. Mean spatial error for Experiments (left panel) and Response Times (right panel) for Experiment 9a. Error bars represent standard error.

Discussion

No effects were found that would evidence an influence of knowledge about the relationship between two individuals on spatial distortions or speed of response. This is in line with the findings of Experiments 8a and 8b and would suggest that high-level cognition does not cause spatial distortions in allocentric representations. However, it is of course possible that participants did not remember the introductory information and were not paying enough attention to the reminder slides. An approach that necessitates the encoding of the relationship by participants might more readily cause spatial distortions on the basis of abstract information. This is investigated in Experiment 9b.

Experiment 9b: Background Knowledge of Interacting Partners II

In order to ensure that participants would process and remember the identity of individuals in the two friendly pairs, and therefore the stranger dyads as well, a memory test was introduced: After each trial, participants had to press one of two keys, corresponding to whether the pair they had just seen was introduced as friends or strangers. This, however, would present participants with a possible strategy that would afford them to still ignore the relationship information and instead associate each pair with the corresponding key rather than the relationship. To avoid this potential confound, the keys associated with each relationship status were randomly chosen (out of 10 options) for each trial.

Methods

Participants

30 more participants from the student pool of the University of York took part in this experiment and reimbursed with course credit or payment.

Materials

Materials used were identical to those used in Experiment 9a. Reminder slides were not used in this experiment.

Design & Procedure

A pairwise comparison was made to investigate differences in Response Times and Spatial Error resulting from knowledge about the Relationship of the presented pair (Friends / Strangers). The procedure was identical to that in Experiment 9a, with the exception that no reminders as to the relationship status were given before each trial (see Figure 5.9). Instead, participants were asked to remember the relationship status and indicate their answer by pressing the corresponding key (randomly chosen out of 10 options for each trial).

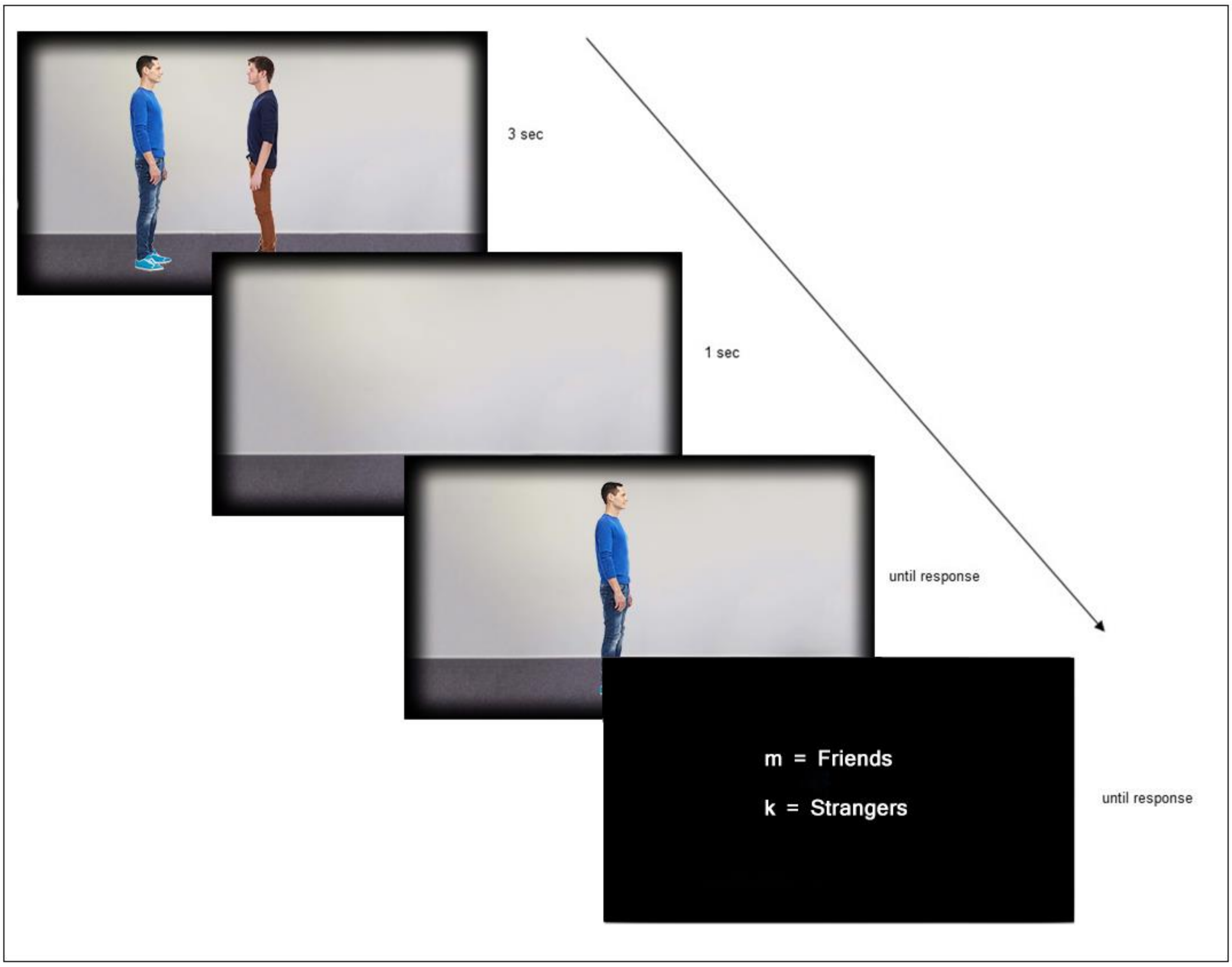


Figure 5.9. Procedure of a Towards oriented dyad with a reappearance of the left partner. A recall of the relationship of the seen pair was required after each trial.

As in the previous experiment, trials with response times below 500ms, above 5000ms or spatial errors more than three standard deviations from the mean were discarded. Additionally, trials in which the participant remembered the relationship information incorrectly were also excluded from further analysis (<8% for each individual participant, <5% overall).

Results

A paired t-test showed no significant difference between relationship conditions in either spatial errors ($t(29)=0.51$, $p=.615$), or response times ($t(29)=0.23$, $p=.824$), see Figure 5.10.

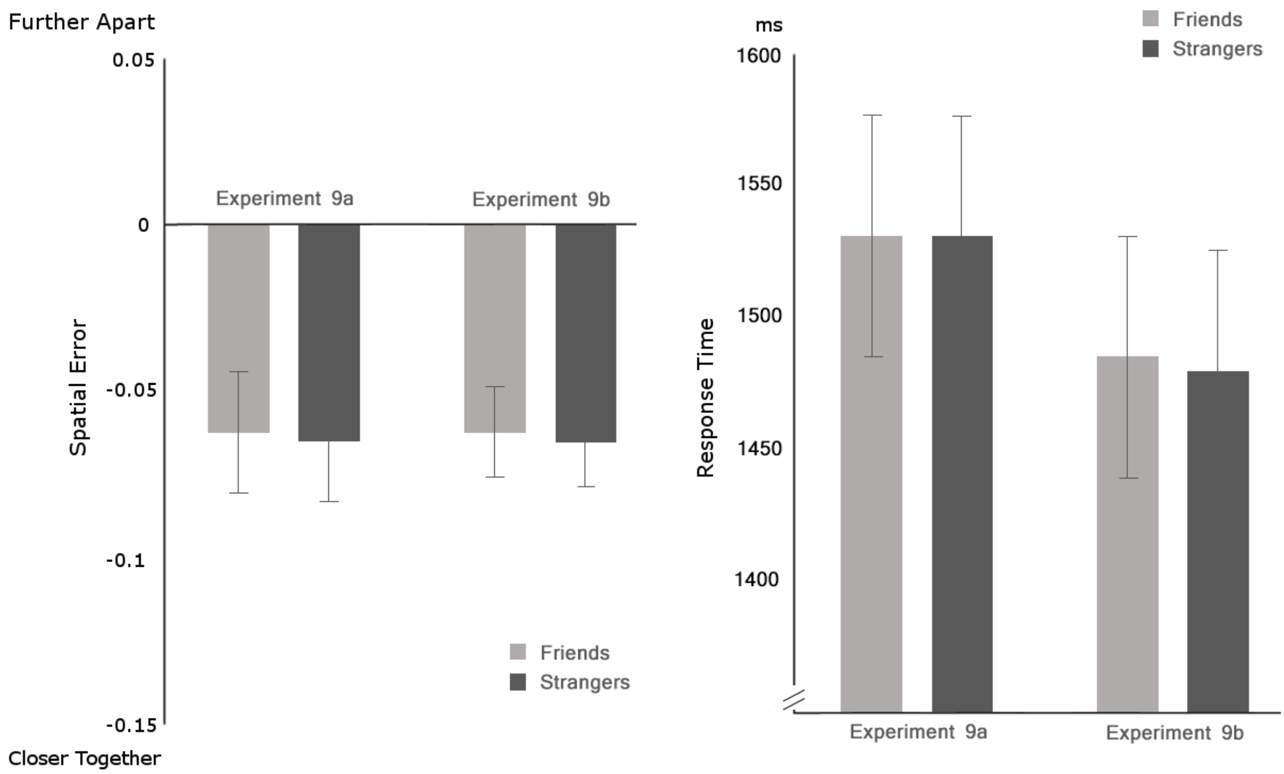


Figure 5.10. Mean spatial error for Experiments (left panel) and Response Times (right panel) for Experiments 9a and 9b. Error bars represent standard error.

Discussion

Neither Experiment 9a nor 9b could find any evidence of explicit knowledge about an interacting pair influencing processing or reconstructive memory in a way that distorts spatial judgments or provides an advantage to response times. These results would further support a binary view of Social Binding in which pairs are only evaluated as to whether they are interacting or not, without the resulting memory engram being further altered by additional information about the quality or intensity of the relationship.

It is important, however, to note that this experiment only investigated the effects of explicit verbal knowledge, not any information about relationship or interaction that is implied by the physical properties of the display itself. As Social Binding suggests that interacting groups are bound into memory in the form of cohesive events, it is possible that these events are only evaluated and influenced by factors that are immediately relevant to the current situation and interaction at hand. For example, Experiment 1b reported in Chapter 2, provided initial evidence that stronger social interactions might provide stronger binding, which subsequently influenced visual search. That is, in the man-boy display there appears to be a more active social interaction which produces greater facilitation when searching for such interactions than is observed from the more neutral man-man interactions.

Aside from situationally relevant information, it is still possible that additional knowledge about a given interacting pair is influencing the binding process as long as that information is visually salient and strongly associated with the person in question. The information given to participants in this experiment was explicit, abstract and not directly observed by the participant within the display. It would be possible to test the core question of Experiment 9a and 9b further by asking participants, instead of just reading about the relationship, to view a video clip showing the pair in question engaging in either friendly or neutral interactions. It is also possible that imagining such an interaction would be enough to prime participants, as has been shown, for example, by Crisp & Turner (2009). And finally, if specific properties have to be visible in the display, perhaps manipulations of ethnicity might be more effective. That is, location of an individual would be recalled as closer when they are viewed as a within-race pair (white-white or black-black) than when recalled from between race pairings (black-white).

Experiment 10a: Human-Like CGI Avatars I

The final experiments will investigate the validity of experimental designs that use computer-generated visual representations (CGI avatars) of humans that are recognisably artificial. This kind of stimulus is especially valuable for research involving 3-dimensional environments and virtual reality paradigms, which would allow for future studies to investigate the concepts presented here in more naturalistic settings. Furthermore, classic 2-dimensional paradigms could potentially benefit from stimuli like these as they do not require models or stock images and body postures, movements as well as facial expressions can be manipulated in more detail. This would allow for more advanced controls for lower-level visual features, which could influence any gathered results.

While it might seem superfluous to test whether Social Interaction exists in avatar-avatar interactions when it has already been shown to exist in human-animal interactions, it is not clear from previous research how well artificial human likenesses are accepted as interaction partners. Existing studies have shown that CGI and robotic human representations suffer from being rated as less likeable, thought to have less agency and perceived as less trustworthy even through implicit measures (Mathur & Reichling, 2016). All these factors might contribute to a failure to socially bind two avatars even with the same features and in the same contexts as the human stimuli used in previous chapters.

Consistent with the other experiments in this chapter, the task requiring recall of spatial location from working memory was employed. This method was more appropriate than visual search, because the stimuli in the latter search tasks are much smaller, and hence whether the stimuli are human or non-human avatars would be much less salient. Furthermore, it is possible that the subtle contrasts between human and avatar stimuli might not be detected at the earlier stages of visual search when stimuli are initially detected, but they might be encoded at later stages of memory encoding and retrieval.

Methods

Participants

30 students from the University of York took part in this experiment and were reimbursed with course credit or payment.

Materials

6 avatars were created using the software MakeHuman (2016). The avatars had identical bodies but different clothing, hair and faces in order to make them recognisable individually. An example of a CGI dyad can be seen in Figure 5.11. The same background and presentation equipment as in Chapters 3 and 4 were used.

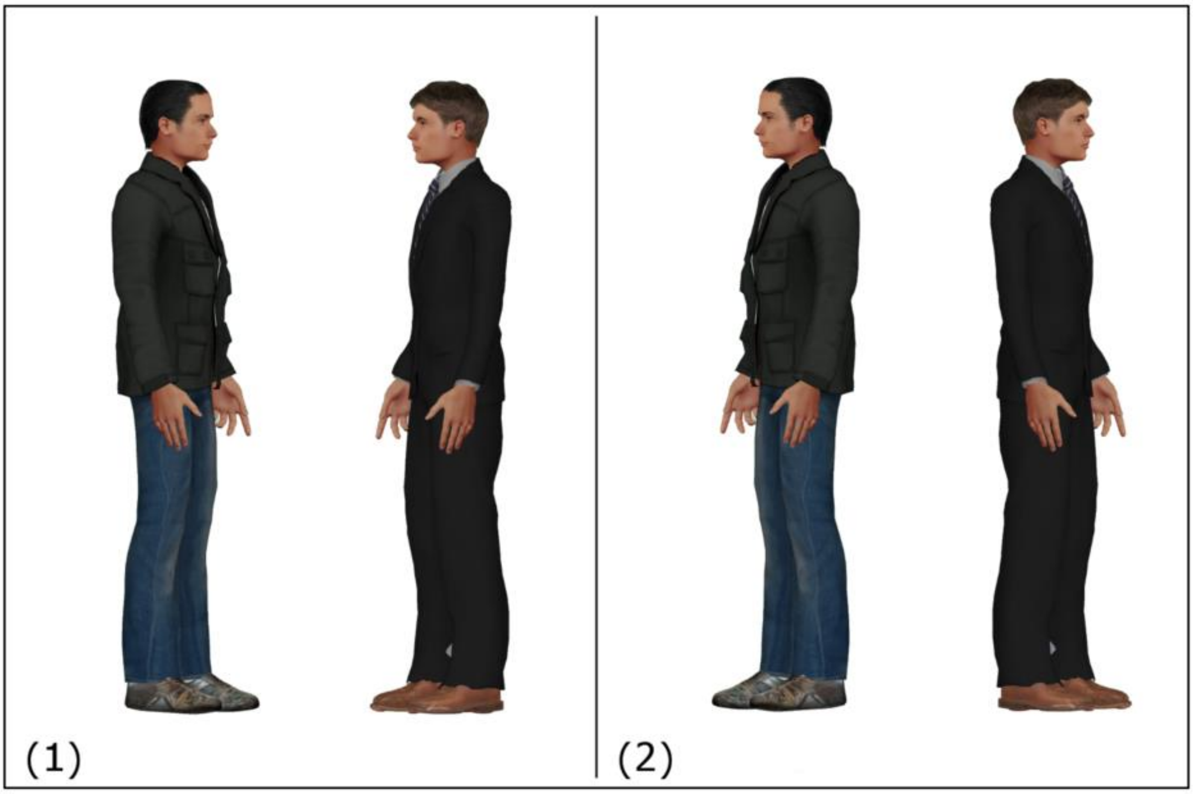


Figure 5.11. Computer-generated and recognisably artificial stimuli in Towards (1) and Away (2) orientation.

Design

A within-subjects design was used to test for differences in Spatial Error and Response Times between Orientations (Towards / Away).

Procedure

The procedure was identical to the one used in Chapter 3. That is, individuals were viewed for 3 seconds, then after a 1 second gap one individual was presented and participants had to recall the location that the other individual would have been. As before, trials were excluded from the analysis if Response Times were shorter than

500ms or longer than 5000ms or if they had Spatial Errors in excess of three standard deviations from the mean (<3% of trials).

Results

A paired t-test revealed no significant difference in Response Times ($t(29)=1.58$, $p=.124$). However, the difference in Spatial Errors between Orientations was significant ($t(29)=2.67$, $p=.012$, $d=0.48$) with Away facing pairs being judged closer together than Towards facing pairs. See Figure 5.12 for a comparison of the conditions.

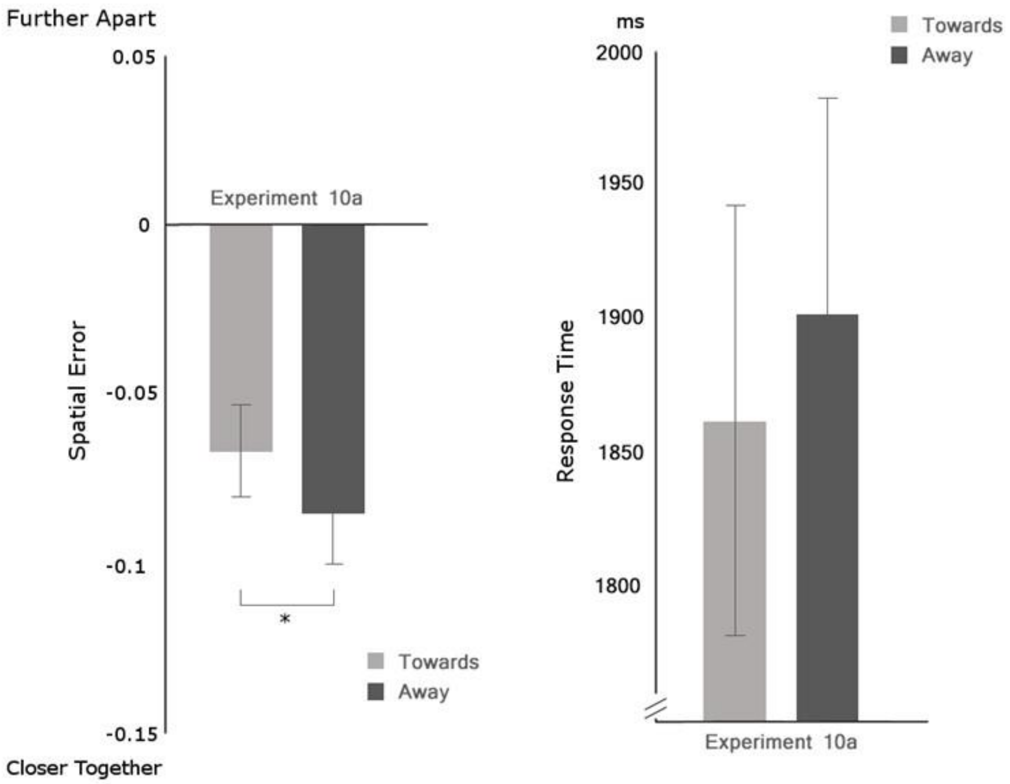


Figure 5.12. Mean spatial error (left panel) and Response Times (right panel) for Experiment 9a. Error bars represent standard error. *$p<.05$

Discussion

While no differences in response times were predicted where there is no Social Binding between CGI avatars, the results were surprising in that these characters displayed a difference in spatial judgments opposite to the differences found in the case of human pairs. Before considering explanations on the basis of higher level cognition and processing differences between human and CGI stimuli, it is necessary to consider explanations on the basis of low-level factors, such as body posture and gestures: While the human stimuli used throughout this thesis took a variety of different postures, their arms were usually at their sides or crossed in front of them. The CGI characters, however, all shared the same body posture with their hands held out in front of them, differentiating them from the human stimuli - for a visualisation of this see Figure 5.13. It is possible that this hand position changed the center of mass sufficiently to cause the unexpected results. It is also possible that the implied gesture was perceived by participants as combative or as the dyad members keeping each other "at arm's length", i.e. indicating their need for distance.

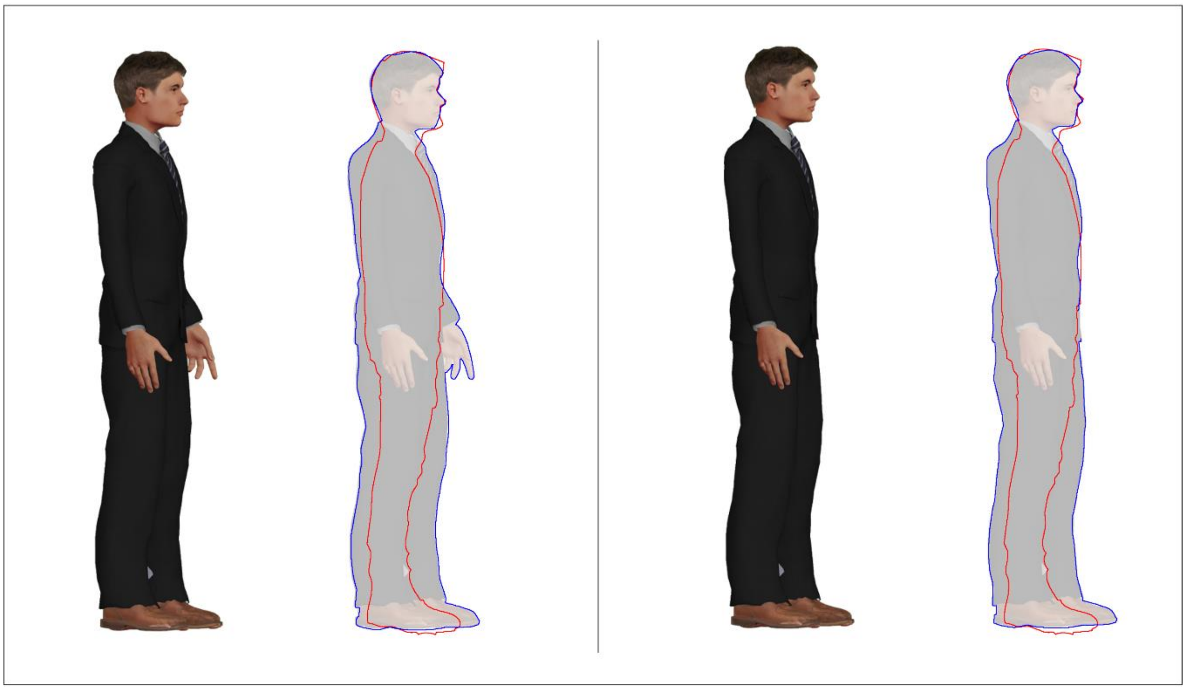


Figure 5.13. A CGI avatar with (left) and without (right) a protruding hand with an outline the original human stimuli (red) overlaid on each avatar (blue). Note that the removal of the hand greatly equalises stimuli.

Experiment 10b: Human-Like CGI Avatars II

Methods

Participants

30 students of the University of York (26 female, 4 male) participated in exchange for course credit or payment.

Materials

The 6 avatars from Experiment 10a were altered to remove the hand that was held in front and make their outline more similar to the human stimuli, as can be seen in Figure 5.13. See Figure 5.14 for an example of a new dyad.

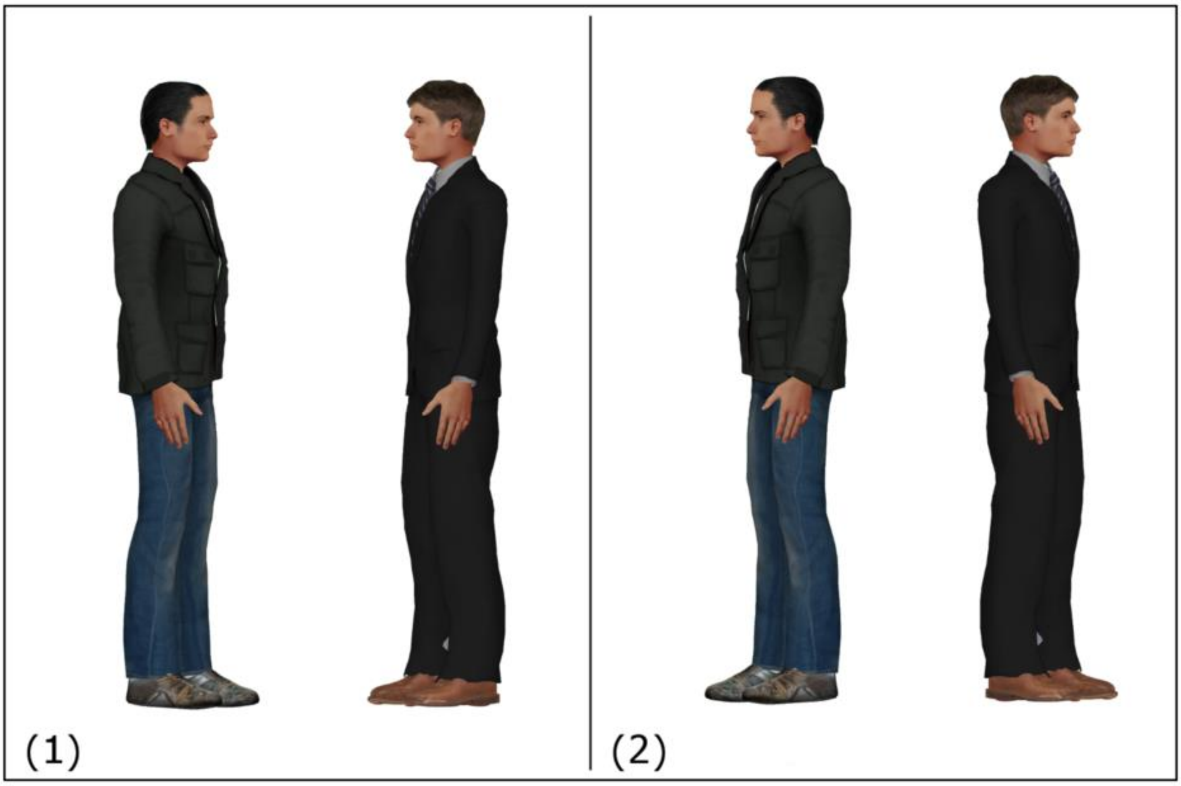


Figure 5.14. Computer-generated and recognisably artificial stimuli without protruding hands in Towards (1) and Away (2) orientation.

Design

Spatial Error and Response Time differences resulting from different Orientation (Towards / Away) were analysed using a within-subjects design.

Procedure

The procedure was identical to Experiment 10a. Trials were discarded if the Spatial Errors were more than three standard deviations away from the mean or if they had Response Times less than 500ms or more than 5000ms (<2% of trials).

Results

A paired t-test revealed the same significant difference in Spatial Errors as before, with Away facing pairs being judged closer than Towards facing pairs ($t(29)=3.07$, $p=.005$, $d=0.54$). There was no difference in Response Times ($t(29)=0.30$, $p=.767$). Results can be seen in Figure 5.50.

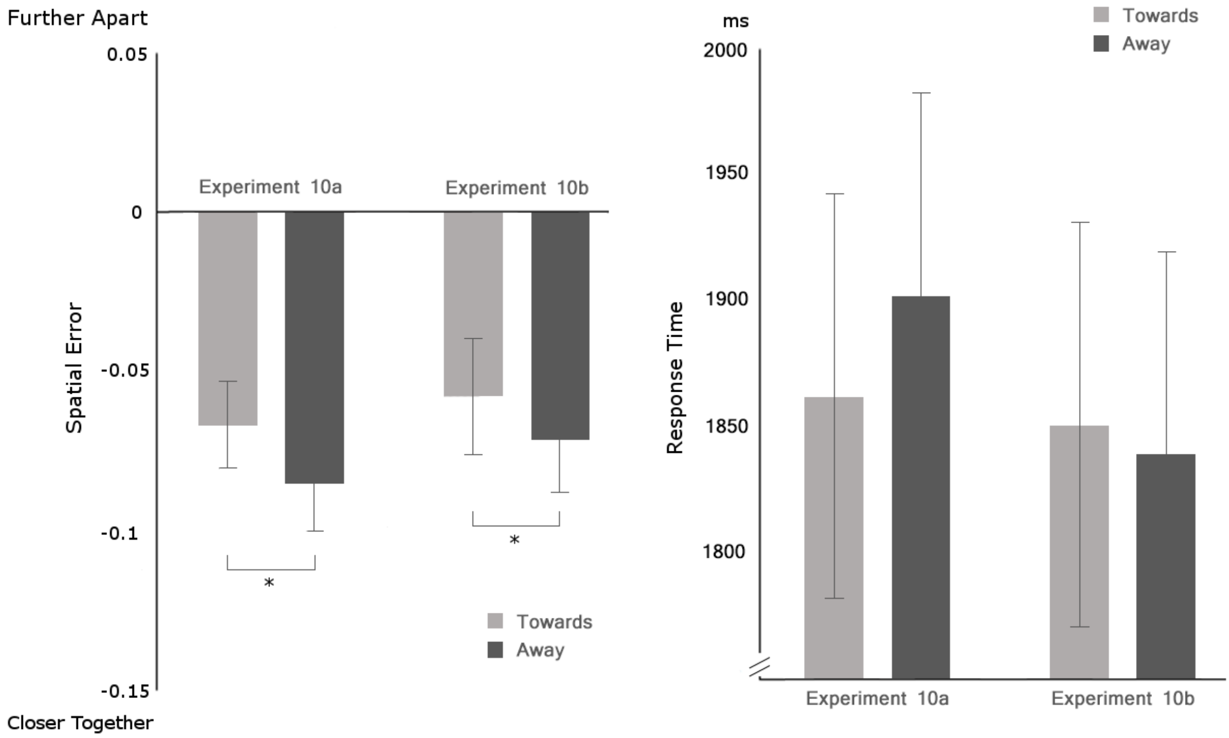


Figure 5.15. Mean spatial error (left panel) and Response Times (right panel) for Experiments 9a and 9b. Error bars represent standard error. *p<.05

Discussion

Experiment 10b confirmed the results from Experiment 10a in that non-facing pairs of CGI characters were remembered as closer together than facing pairs. Response Times were nonsignificant here as well. The lack of a significant difference in Response Times in either this or the previous experiment supports the conclusion that there is no Social Binding for recognisably artificial representations of human characters. However, finding spatial judgments that appear to show a repulsion effect, where interacting partners are recalled as <u>further</u> away, was a completely unexpected finding. This new observation is opposite to that which has been repeatedly reported throughout the thesis, where humans who appear to interact are recalled as closer together. At this stage there is no clear explanation. However, it should be noted that the effects are unlikely to be due to low-level differences between avatar and human displays. Of particular note is that the task required participants to report the location of the head of the individual who is not visible. As can be seen in the right Panel of Figure 5.10, the avatar and human head properties are almost identical.

Chapter 5 - General Discussion

The thesis has demonstrated that basic social interactions appear to be computed rapidly even when participants are never asked to consider the nature of the interaction. That is, there is a rapid analysis of whether two people are interacting or not, and this information is available to a wide range of cognitive processes: Thus, social binding facilitates search for a visual target, it can influence the recall of spatial location from working memory, and it can determine the efficiency of retrieval from longer-term memory. Hence the initial computations of social interactions have ubiquitous effects throughout cognitive systems.

However, thus far the perception of the social information can be determined by physical cues in the display. That is, whether people are looking towards or away from each other. The current chapter has started to examine whether some of the effects detected can also be observed when non-physical features are manipulated (Experiments 9a & 9b) and whether higher level properties such as emotion can influence the basic social binding process (Experiments 8a and 8b). For example, when people are observed to interact with animals, the towards/away effects previously observed have been detected. That is, beyond interactions between two people, when a person is looking towards an animal the animal is recalled as closer. However, the potential threat posed by the animal does not appear to be encoded in such allocentric frames (though it is established in egocentric frames).

In a converging approach examining emotion and personal affiliation, Experiments 9a and 9b found no effects when people were believed to be close friends as compared to strangers. Importantly, in these studies there are no physical cues in the visual images as to the friendliness status of the pair of people, it is only provided by verbal descriptions. A prediction was that close friends would have been recalled as physically closer. This was not observed even when participant had to explicitly make this judgment of friendliness on every trial. Hence, as with the negative emotion evoked by threat, the positive emotions of affiliation have no effect when observed in allocentric perspectives, whereas, again, they are detected in egocentric frames.

The theoretical implications of these findings will be discussed further in the final chapter. However, for now, it is suggested that the Social Binding investigated in this thesis is a mid-level form of representation based on rapid analysis of the physical forms of social interactions. This representation provides initial analysis and input into further more sophisticated forms of social interactions. This social binding representation is modular, in the sense that it will provide feed-forward information to higher forms of representation, but does not accept feedback information, such as the emotions evoked by the observed interaction. The lack of effects of emotion in the allocentric representations when passively observing the interactions between other people and objects is in sharp contrast to egocentric forms of processes, where emotion is directly linked to observing participant.

The second issue investigated in this chapter was to examine whether the social binding effects observed in previous chapters are computations of human social interactions. It is possible that very similar displays, but which are clearly non-human, might produce similar social binding effects. If such results were indeed obtained while perceiving non-human avatars, then this would suggest the social binding system is somewhat general, not specific to computing human social interactions. To test this idea, Experiments 10a and 10b replicated the prior spatial distortion effects, but in this case they employed avatars.

The results from these studies produced unexpected results. Although there were no RT effects, which might suggest that avatars do not produce social binding effects, there were in fact distortions of spatial memory, suggesting the implied social interactions in towards and away displays was indeed computed. However, what was not expected was the direction of the effect, which was opposite to that previously observed. That is, towards facing avatars were recalled as further apart than away facing avatars.

For now it can only be speculated as to the reasons for the reversal in the spatial memory distortions. For example, Mathur and Reichling (2016) have shown that artificial human likenesses are perceived as less likeable and less trustworthy not just in explicit but also implicit ratings. Hence they argued that artificial human-like characters are at least, in these instances, processed as a separate category to representations of actual humans. In this regard the results might be exemplary of the controversial concept of the "Uncanny Valley" (Burleigh, Schoenherr, Lacroix, 2013), a phenomenon where artificially created characters elicit a feeling of "wrongness" or "otherness" (Kätsyri, Förger, Mäkäräinen & Takala, 2015) in an observer, leading to the above mentioned differences in ratings. This perception of otherness could impede an observer's ability to imagine or predict the characters to be interacting. The outward bias in the facing pairs might reflect an additional inclination of the observer to keep apart two characters or objects that might interact in an unpleasant way. Further studies that present avatars interacting in typical human ways might reduce the uncanny valley effects and produce effects similar to those of the human social binding processes.

In sum, this final experimental chapter has started some further lines of research, but has only provided a glimpse of what might yet be discovered. It would seem that emotion and social affiliation does not feedback in to the social binding processes. However, whether social properties such as affiliation can have effects when marked by visual features (e.g., ethnicity) is a distinct possibility. Similarly, the surprising reversed effects when viewing avatars needs replication and extention. At the very least, the rapidly growing research field utilizing Virtual Reality (VR) to study social cognition must be cautious. The use of avatars might not justify generalization to human social behaviour.

Chapter 6:

General Discussion

Summary

The experiments in this thesis investigated the processing of allocentric third-person interactions between other people. That is, unlike previous research that has primarily been based on egocentric computations where the states of the observer, or the relationship between the observer and observed, have been important; the present work presented interactions between two other people, which were essentially irrelevant to the observer. Hence participants did not have to consider and analyse any properties of the people in view, rather they simply had to detect and localize targets which were (non-)interacting pairs, recall the relative spatial location of individuals after viewing them and recall visual features of those individuals. The hypothesis was that when encountering complex social environments containing a number of people, an important initial computation was to detect where social interactions are taking place as an initial structural representation on which subsequent more sophisticated analysis of social interactions, such as detection of deception, social intimacy etc., might be built.

This way of simplifying and quickly evaluating complex displays is most reminiscent of the well-established mechanism of perceptual grouping. This fundamental process binds separate visual elements and features together into perceptual wholes according to Gestalt principles, such as proximity, similarity, good continuation or closure (e.g., Coren & Girgus, 1980). Perceptual grouping is known to result in faster processing (Woodman et al, 2003) and decreased perceived distance of the individual elements, such as open versus closed brackets (Coren & Girgus, 1980). It was hypothesised that similar grouping principles might also take place when perceiving interacting people, which would provide a rapid and simplified framework for subsequent more subtle social analysis.

The Social Binding hypothesis relies on the assumption that such an initial computation would be advantageous in quickly identifying interacting groups within a social scene. Chapter 2 has shown that interacting dyads are indeed located more quickly than those that are not interacting. If the proposed mechanism of Social Binding follows similar processes as perceptual binding (e.g., Coren & Girgus, 1980) by not just detecting social interactions more quickly but also associating the members with each other and holding an engram of the entire group, rather than individuals, in working memory, which is subsequently stored in longer term memory. Similar processes have been shown to lead to underestimated distances between components (Buehner & Humphreys, 2009) and faster retrieval of one in the presence of the other (Alvarez, 2011). Both effects have been found to occur for interacting groups as well in Chapter 3, with interacting partners being remembered as closer and this information was retrieved more rapidly than non-interacting partners. If this same group-level engram is also stored in longer term memory then it would be expected that the memory accuracy for partners in the presence of the other (e.g., Horner & Burgess, 2013) but also independent of the presence of the partner (e.g., Woodman et al., 2003) would be increased. The exception to this are situations in which information about features of the partners is stored as general group information and cannot easily be devolved into individual information (Im & Chong, 2014; Corbett, 2016), leading to a decrease in accuracy. This pattern of performance was found in Chapter 4 with individual features of the partners seemingly associated with the group the individual belongs to. This leads to decreased memory accuracy when participants were tasked with remembering which partner a given feature - in this case body - belonged to.

Overall, the results are consistent with a Social Binding model: Although irrelevant to task demands, the socially interactive nature of the observed people was computed leading to faster detection/localization of interacting dyads and distortions of space in short-term memory and generally increased accuracy of recall in longer-term memory but decreased accuracy when features of interacting partners have to be discriminated.

Various lower level explanations, such as symmetry, gaze cueing, attention or representational momentum were investigated, but failed to explain the pattern of results. While similar perceptual grouping effects of objects according to gestalt principles have been found in the past (e.g., Coren & Girgus, 1980), none of the known principles can account for the current effects as the Towards and Away orientations do not vary in proximity or similarity, nor do they form a common figure to which the laws of closure or good continuation could be applied.

From this foundation of a Social Binding model, further investigations were undertaken in Chapter 5 to determine the factors that facilitate binding and potential avenues for future research. No clear evidence of higher level cognition altering the binding process was found, however open questions were highlighted that warrant additional studies.

Social Binding beyond Binary Interactions

The biggest uncertainty about the concept of Social Binding is whether binding is a binary process that is only based on whether a given pair is interacting or whether binding processes can vary in intensity depending on the interaction observed. This may either happen at the point of binding or through processes that alter the resulting group representation at later stages or during reconstructive retrieval.

As shown in Experiments 8 and 9, abstract information, such as whether participants are told that two individuals are close friends, does not seem to have an effect on grouping either in terms of the strength of the binding process or later alterations to spatial memory. However, some results would still support this possibility: The significant difference in effect sizes between the reaction times when searching for symmetric adult-adult pairs or asymmetric adult-child pairs in Experiments 1 and 2 may be explained by some stronger social relationships (e.g. parent-child) or strong interactions leading to stronger Social Binding. It is of course also possible that the binding in the case of the adult-child pair simply happened sooner due to stronger interaction cues being present in the stimuli. This would have led to the larger advantage in locating grouped pairs in the adult-child pairs while the association itself between the partners might not have been any stronger than in the symmetric adult-adult pairs.

The other finding that might indicate that processes beyond a simple evaluation of interaction influence Social Binding is the reversal of spatial errors in Experiment 10, when avatars are viewed. A lack of grouping of artificially generated characters would not be conflicting with a binary Social Binding model, however the fact that facing pairs were remembered further away than non-facing pairs might be indicative of cognitive biases towards these stimuli affecting the group representation in visual working memory. Therefore, although the current findings reveal the warping of spatial memory in a passive task where no actions are required and the object properties are of little relevance to the spatial memory task, the possibility of egocentric processes or expectations influencing the current effects cannot be ruled out. It is possible that egocentric computations in space perception such as those found by Jung et al. (2016)

are applied when observing allocentric interactions between two other people by way of perspective taking.

Furthermore, other studies have shown that properties of an egocentric frame of reference can influence allocentric judgements of distance. For example, judgements of the length of a line are influenced by an observer's level of fatigue: after an effortful task has produced fatigue, lines are judged as longer (Clark, Ward & Kuppuswamy, 2016). Hence it may be the case that the states of the participant, such as social inclusion/exclusion, emotion, task goals, and ingroup/outgroup perceptions could also influence the warping of allocentric spatial memory.

On the other hand, it is possible that the basic effects revealed in the current studies are not affected by feedback from higher-level states of the perceiver (e.g., emotion, empathy etc.) or the observed social interaction (e.g., dominance, intimacy etc.). Rather, it is possible that the automatic detection of a social interaction is a mid-level representation that automatically facilitates detection and localisation of interacting dyads as well as influencing later memory. This process could be modular and not influenced by feedback from higher-level social processes. Rather, this initial automatic computation extracting social interactions might provide the automatic input to these later, higher-level social computations. This is visualised in Figure 6.1, which gives a representation of the proposed model of Social Binding. Note that higher level cognition only influences whether a given scene is bound, but does not directly influence any of the further processing of the bound stimulus.

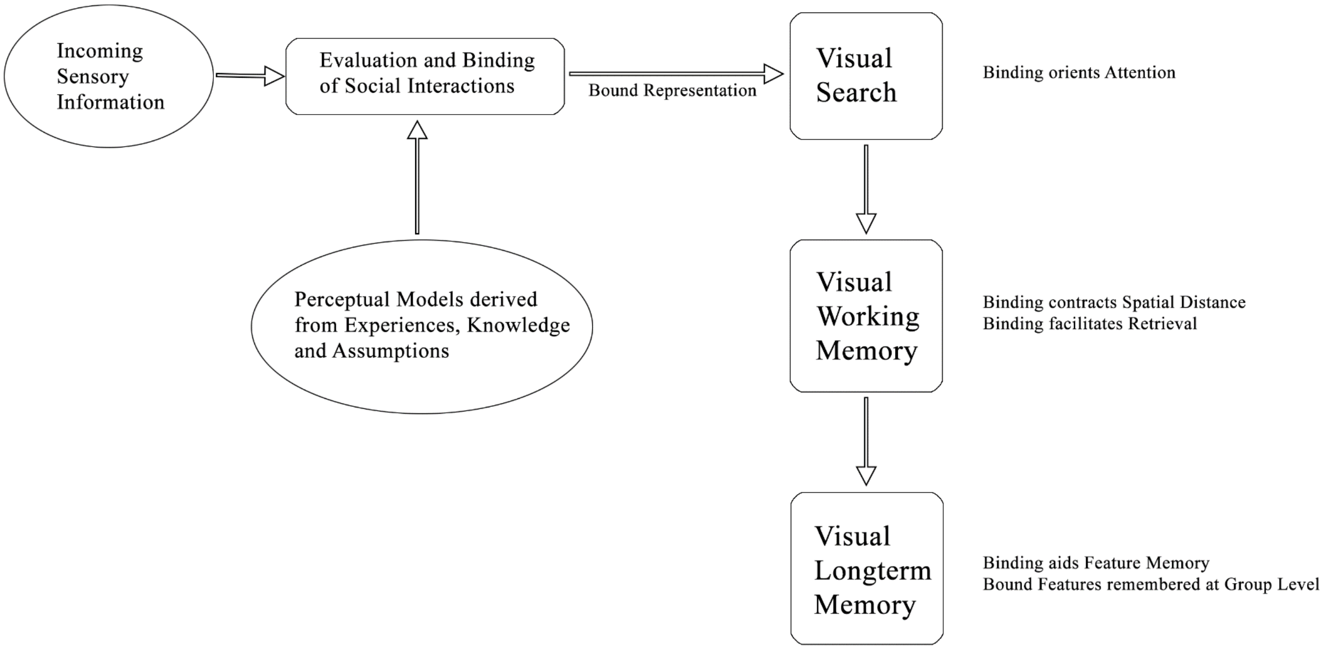


Figure 6.1. The Model of Social Binding. A representation of the proposed model, including influences on the binding process and the effects of binding throughout the visual cognitive stages.

Social Binding in Context of Non-Social Binding Processes

The social effects observed here may be part of a more general principle in which interacting stimuli are given preference and space is contracted between them. This is demonstrated even in simple interactions between objects. For example, in situations where a circle moves and then collides with a rectangle, which immediately causes a second circle to move, the length of the intervening rectangle is recalled as shorter than when there is no causal relationship between the two circle objects (Humphreys & Buehner, 2010). Furthermore, there is evidence for similar binding with objects that are perceived to be interacting, such as a hammer striking a nail (e.g., Bach, Peelen & Tipper, 2010; Riddoch, Humphreys, Edwards, Baker, & Wilson, 2003). The findings of this thesis reveal that these distortions of spatial memory may be caused by a gestalt-like principle of interaction and can also be identified with higher-level social interactions, where the potential for interaction is only implied and not overtly perceived via movement cues. This thesis proposes that when two people are jointly engaged in a social situation, they are grouped and encoded as one event, in a similar way to two interacting objects. This jointly encoded unit results in faster retrieval of the prior spatial information, and increased spatial proximity in such memory representations. Moreover, even higher level properties of the dyad members are grouped in such a way and accessed more rapidly. The results of Experiments 5 and 6 especially provide support for the binding account, where recall of the properties associated with interacting individuals such as the person identity, direction the person faced or the color of their shirt, was better than that of non-interacting individuals, in a manner similar to von Hecker, Hahn and Rollings (2016).

Social Binding in Context of the Current Literature

The results of the reported studies show that Social Binding as a theoretical framework is able to explain and integrate some of the recent findings in the literature. The two-body inversion effect found by Papeo et al. (2017) can be explained by facing dyads used in their study being socially bound and therefore processed preferentially, leading to their participants being able to identify human dyads more accurately. The apparent elimination of any binding effects in inverted dyads has been replicated here in Experiment 1.

This elimination of low level and "non-social" effects also provides support in favour of a social explanation of Jung et al.'s (2016) results. While it is certainly possible that their effects of decreased distance estimates when looking at the front of a virtual avatar might be explained by low level processes, the results presented here have now shown similar effects in an allocentric frame with decidedly different low-level visual information and would favour a higher level explanation.

Final Comments

Finally, an advantage of the range of techniques, from immediate perception in the target detection task to retrieval from later memory, is that examining such cognitive processes of perception and memory can provide new converging methods to explore the automatic computations of social relationships. That is, the automatic processing of the relationships may reveal higher-level information and judgments in the distortion of spatial memory and the speed of access to this memory. Such an approach could investigate individual differences in social cognition, such as depression (e.g., Bayliss, Tipper, Wakeley, Cowen, & Rogers, 2016) and autism (Shah & Sowden, 2015) in an implicit manner. For example, do people with autism also automatically compute social interactions so that their attention is more rapidly oriented to such interactions, and do memory retrieval processes reflect these computations?

The appearance of social binding in these simple laboratory experiments raises several new questions about the interaction of social perception and higher-level social processing, and it opens up new possibilities for research. While it is up to future studies to explore the relationship between the automatic detection of social interactions, properties of the stimulus and states of the observer, the current series of studies has shown that interacting individuals are perceptually grouped according to a previously unknown late-stage gestalt-like principle that binds interacting partners into memory as single events.

Appendix A

Results Tables

Chapter 2

DV = Key Pressed

ANOVAs

	Orientation			Stimulus			Orientation x Stimulus		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 1	13.77	<.001	.192	10.52	.002	.154	6.25	.015	.097
Experiment 2	20.99	<.001	.266	0.12	.736	-	18.65	<.001	.243
Combined	60.58	<.001	.511	22.22	<.001	.277	9.24	.004	.137

Descriptives & Posthoc Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Upright	1.09	0.03	1.19	0.03	-0.10	0.16	0.03	3.45	.002	0.63
Inverted	1.27	0.04	1.29	0.03	-0.02	0.08	0.01	1.39	.174	-
Asymmetric	1.29	0.05	1.53	0.05	-0.24	0.18	0.03	7.40	<.001	1.33
Objects	1.38	0.06	1.39	0.05	-0.01	0.23	0.04	0.17	.870	-

DV = Movement Time

ANOVAs

	Orientation			Stimulus			Orientation x Stimulus		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 1	1.63	.207	-	0.45	.506	-	0.02	.882	-
Experiment 2	0.17	.680	-	0.16	.690	-	1.54	.219	-

Descriptives & Posthoc Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Upright	0.55	0.02	0.56	0.02	-0.01	0.04	0.01	0.82	.417	-
Inverted	0.58	0.02	0.58	0.02	-0.01	0.04	0.01	0.98	.336	-
Asymmetric	0.57	0.04	0.59	0.04	-0.02	0.09	0.02	1.25	.221	-
Objects	0.62	0.08	0.61	0.06	0.01	0.1	0.02	0.55	.585	-

DV = Key Pressed + Movement Time

ANOVAs

	Orientation			Stimulus			Orientation x Stimulus		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 1	15.66	<.001	.213	11.05	.002	.160	7.69	.007	.117
Experiment 2	18.16	<.001	.238	<0.01	.985	-	18.93	<.001	.246

Descriptives & Posthoc Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Upright	1.58	0.05	1.74	0.04	-0.16	0.24	0.04	3.63	.001	0.67
Inverted	1.85	0.05	1.88	0.04	-0.03	0.1	0.02	1.57	.126	-
Asymmetric	1.87	0.07	2.12	0.07	-0.26	0.20	0.03	7.34	<.001	1.3
Objects	2.00	0.08	1.99	0.06	0.01	0.26	0.05	0.06	.956	-

Chapter 3

DV = Spatial Error

ANOVAs

	Orientation			Stimulus			Orientation x Stimulus		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 3	1.30	.259	-	2.12	.151	-	10.31	.002	.151
Experiment 4	9.48	<.001	.434	-	-	-	-	-	-

Descriptives & Posthoc Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
People	-0.082	0.015	-0.061	0.015	-0.021	0.031	0.006	3.59	.001	0.68
Objects	-0.030	0.059	-0.040	0.058	0.010	0.041	0.015	1.30	.203	-
Scrambled	-0.085	0.014	-0.091	0.014	0.005	0.019	0.004	1.46	.156	-

	Towards		Away		Left		Right	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Experiment 4	-0.106	0.011	-0.074	0.011	-0.077	0.010	-0.076	0.011

DV = Response Time

ANOVAs

	Orientation			Stimulus			Orientation x Stimulus		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 3	3.93	.052	-	3.60	.063	-	5.84	.019	.091
Experiment 4	10.66	<.001	.464	-	-	-	-	-	-

Descriptives & Posthoc Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
People	1.84	0.08	1.89	0.08	-0.05	0.1	0.02	2.92	.007	0.5
Objects	1.69	0.06	1.68	0.06	0.01	0.08	0.02	0.33	.743	-
Scrambled	1.82	0.08	1.84	0.08	-0.01	0.07	0.01	1.06	.297	-

	Towards		Away		Left		Right	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Experiment 4	1.72	0.05	1.79	0.05	1.79	0.05	1.79	0.05

Chapter 4

Encoding

DV = Spatial Error

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Experiment 5	-0.076	0.008	-0.059	0.007	-0.017	0.036	0.006	3.04	.004	0.47
Experiment 6	-0.093	0.010	-0.080	0.011	-0.013	0.036	0.005	2.83	.006	0.36
Experiment 7	-0.092	0.011	-0.075	0.011	-0.017	0.047	0.007	2.28	.028	0.36

DV = Response Time

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Experiment 5	1.75	0.065	1.81	0.063	-0.06	0.135	0.021	2.73	.009	0.44
Experiment 6	1.66	0.044	1.70	0.045	-0.05	0.126	0.016	2.80	.007	0.37
Experiment 7	1.79	0.050	1.87	0.058	-0.09	0.115	0.018	4.72	<.001	0.78

Memory

DV = Memory Accuracy

ANOVAs

	Orientation			Memory Feature			Orientation x Feature		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 6	32.45	<.001	.359	48.02	<.001	.453	5.70	.020	.090

Descriptives and (Posthoc) Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Identity Recall	.695	.018	.630	.024	.065	.141	.022	2.92	.006	0.46
Orientation Recall	.654	.183	.532	.181	.122	.135	.025	4.95	<.001	0.90
Color Recall	.790	.022	.740	.022	.050	.096	.017	2.87	.008	0.52
Body Recall	.605	.015	0.661	.015	-.057	.114	.018	3.13	.003	0.50

DV = Response Time

ANOVAs

	Orientation			Memory Feature			Orientation x Feature		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 6	0.51	.480	-	1.91	.172	-	7.28	.009	.111

Descriptives and (Posthoc) Tests

	Towards		Away		Difference			Posthoc Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Identity Recall	2.52	0.14	2.52	0.13	-0.003	0.72	0.11	0.03	.997	-
Orientation Recall	2.26	0.09	2.39	0.10	-0.13	0.29	0.05	2.43	.022	0.45
Color Recall	2.53	0.09	2.45	0.06	0.08	0.30	0.05	1.40	.174	-
Body Recall	2.57	0.13	2.59	0.13	-0.02	0.60	0.09	0.22	.830	-

Chapter 5

DV = Spatial Error

ANOVAs

	Orientation			Threat			Orientation x Threat		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 8b	14.27	.001	.330	1.06	.313	-	1.50	.231	-

Descriptives and Statistical t-Tests

	Threatening		Non-Threatening		Difference			Statistical Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Experiment 8a	-0.106	0.014	-0.106	0.013	-0.00004	0.096	0.018	0.003	.998	-

	Towards		Away		Difference			Statistical Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Experiment 8b	-0.092	0.010	-0.072	0.008	-0.02	-	-	-	-	-
Experiment 9a	-0.065	0.015	-0.067	0.016	0.003	0.035	0.006	0.44	.661	-
Experiment 9b	-0.064	0.012	-0.067	0.012	0.003	0.033	0.006	0.51	.615	-
Experiment 10a	-0.066	0.013	-0.082	0.013	0.016	0.033	0.006	2.67	.012	0.48
Experiment 10b	-0.057	0.015	-0.072	0.015	0.015	0.028	0.005	3.07	.005	0.54

DV = Response Time

ANOVAs

	Orientation			Threat			Orientation x Threat		
	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Experiment 8b	5.70	.024	.164	2.29	.141	-	0.82	.373	-

Descriptives and t-Tests

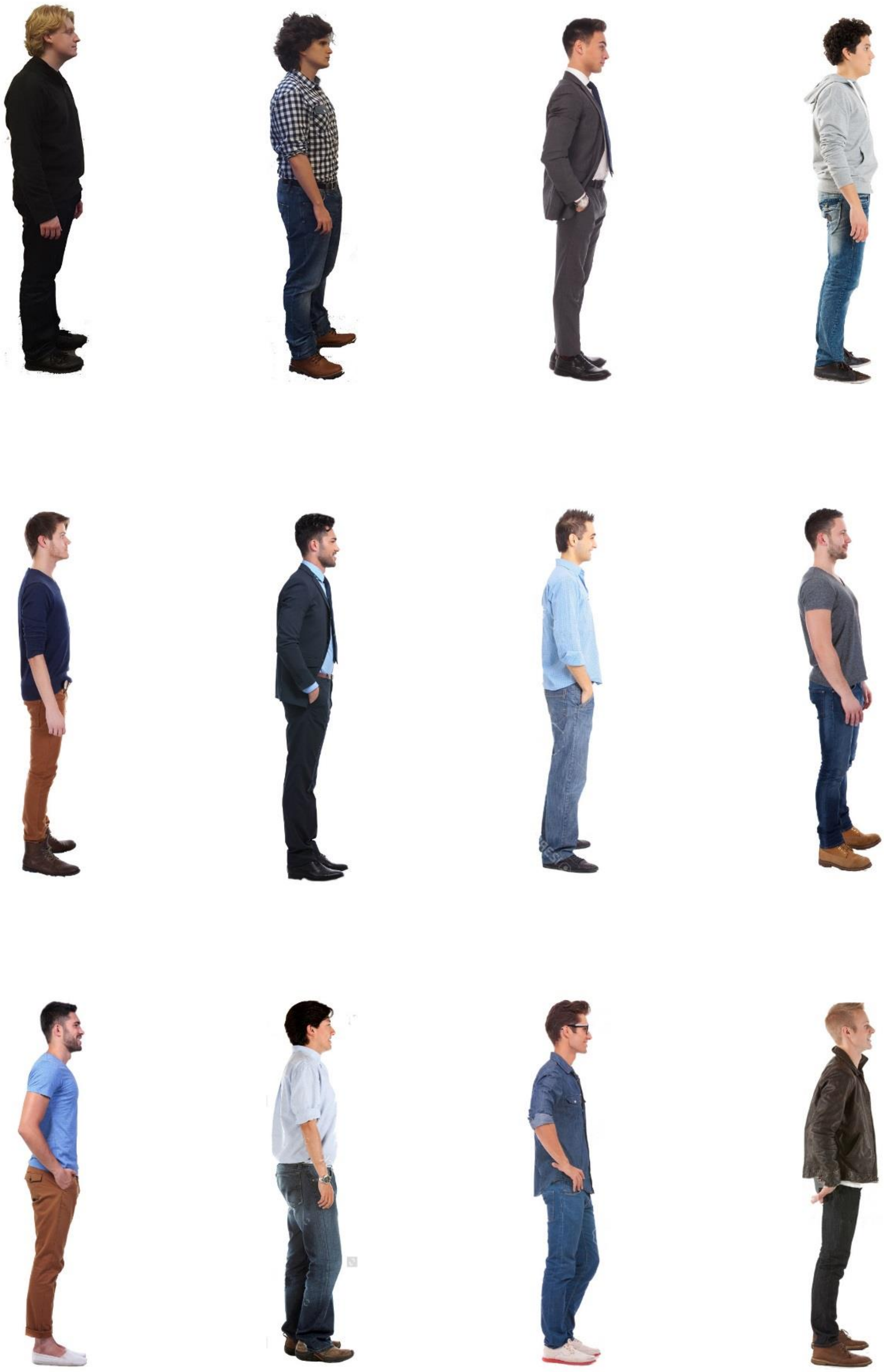
	Threatening		Non-Threatening		Difference			Statistical Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Experiment 8a	1.85	0.08	1.85	0.08	0.0008	0.11	0.02	0.036	.971	-

	Towards		Away		Difference			Statistical Tests		
	Mean	SE	Mean	SE	Mean	SD	SE	t	p	d
Experiment 8b	1.44	0.04	1.48	0.04	-0.04	-	-	-	-	-
Experiment 9a	1.53	0.05	1.53	0.04	0.007	0.10	0.02	0.36	.724	-
Experiment 9b	1.49	0.04	1.48	0.04	0.004	0.10	0.02	0.23	.824	-
Experiment 10a	1.86	0.07	1.90	0.08	-0.05	0.16	0.03	1.58	.124	-
Experiment 10b	1.85	0.08	1.84	0.07	0.009	0.17	0.03	0.30	.767	-

Appendix B

Human Stimuli

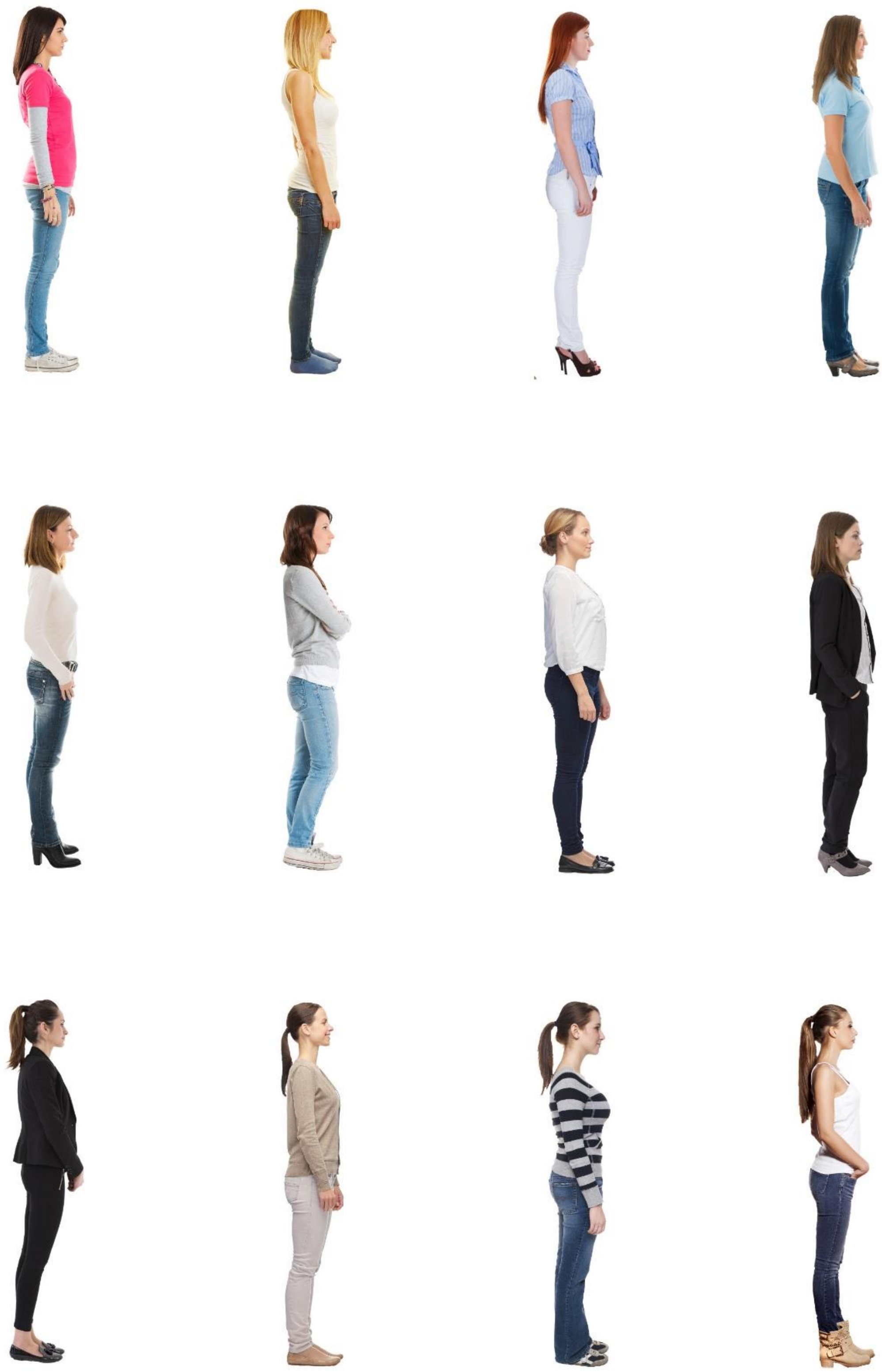
(Chapter 4)









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