A Matching Advantage for Dynamic Human Faces

by

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ABSTRACT

In a series of three experiments, we used a sequential matching task to explore the impact of non-rigid facial motion on the perception of human faces. Dynamic prime images, in the form of short video sequences, facilitated matching responses relative to a single static prime image. This advantage was observed whenever the prime and target showed the same face but an identity match was required across expression (Experiment 1) or view (Experiment 2). No facilitation was observed for identical dynamic prime sequences when the matching dimension was shifted from identity to expression (Experiment 3). We suggest that the observed dynamic advantage, the first reported for non-degraded facial images, arises because the matching task places more emphasis on visual working memory than typical face recognition tasks. More specifically, we believe that representational mechanisms optimized for the processing of motion and/or change-over-time are established and maintained in working memory and that such "dynamic representations" (Freyd, 1987) capitalize on the increased information content of the dynamic primes to enhance performance.

INTRODUCTION

In his book “States of Mind”, Jonathan Miller asked Sir Ernst Gombrich, the renowned art historian, why faces are so hard to represent pictorially. Gombrich replied, “I think it is movement which is the great problem. And in particular the facial movement of expression which impresses us through its changes, through its melody...the characteristic of the person will always be the way they move, the melody of the expression; this can never be caught in snapshots...” (Miller, 1983). As if inspired by Gombrich’s words (see also Gombrich, 1960;1982), there has recently been a growing interest in the role that motion might play in the *mental* representation of facial identity. These studies have examined how rigid rotations of the whole head (e.g., Pike, Kemp, Towell & Phillips, 1997; Schiff, Banka and De Bordes Galdi, 1986) as well as non-rigid transformations of expression, gesture or visible speech (e.g., Bruce & Valentine, 1988; Knight & Johnston, 1997) might influence the way we recognize specific faces.

For example, several studies have now shown convincingly that *rigid* rotations of the head can give rise to better recognition performance when compared to static images. This appears to be true regardless of whether the motion is present at time of study (Pike et al., 1997) or time of test (Schiff et al., 1986). Pike et al. (1997) suggest the success of this approach may be due to the fact that seeing a face continuously rotate through a variety of viewpoints facilitates the extraction of 3-D structural information. Previous studies (e.g., Bruce & Langton, 1994; Kemp, Pike, White & Musselman, 1996) have demonstrated that such 3-D information may well enhance recognition performance.

Studies examining the influence of *non-rigid* motion provide a picture that is far less clear. For instance, an early study by Bruce & Valentine (1988) found very little support for the notion that studying dynamic faces was any different from studying static images. However, more recently, Knight & Johnston (1996) were able to show recognition advantages for moving *famous* faces, but only when the image quality was severely reduced by presenting photographic negatives. Lander, Christie, & Bruce (1999) were able to replicate and extend this work, finding strong advantages for recognizing famous moving faces using two types of degraded images, photographic negatives, as in Knight & Johnston (1996), and "threshold" manipulated images (i.e., one-bit per pixel black and white images).

Christie & Bruce (1998), on the other hand, were unable to find recognition advantages for moving faces when participants studied *unfamiliar* faces. They suggest that this difference between familiar and unfamiliar faces could have arisen if motion were more important for *accessing* existing representations of faces, rather than for *establishing* new representations. As we become more familiar with a face we might begin to incorporate characteristic motion as a specific cue to memory (e.g., Clint Eastwood's squint may be a strong cue to his identity). Lander & Bruce (2000), however, also note that there might be some "generalized benefit" for recognizing moving faces in addition to specific patterns of characteristic motion. That is, a naturally moving face may afford some immediate representational advantage compared to a static image of a face. It is unclear why such a generalized advantage should be found with famous, but not with unfamiliar faces.

The studies discussed thus far have typically explored the role of motion within the context of old/new recognition tasks. That is, performance was assessed by asking observers to judge whether they had previously seen a target face prior to a testing session. Memory for the old target faces could have been established prior to the experiment, in the case of famous faces (e.g., Lander, Christie & Bruce, 1999) or during an explicit study phase, in the case of unfamiliar faces (e.g., Christie & Bruce, 1998). The existence of retention intervals between study and test, lasting at least several minutes, means that such tasks are necessarily probing long-term representations of faces.

In contrast to these old/new tasks, the studies reported here used the, immediate matching paradigm shown in Figure 1. On each trial, observers were shown two faces in quick succession and were asked to make a speeded response based on the information presented during that trial. In Experiments 1 & 2, observers were asked to judge whether the two faces had the same identity. In Experiment 3 the matched dimension was facial expression. The influence of facial motion was explored by manipulating the nature of the initial or "prime" image. In one half of the trials this prime image was a single still image (Figure 1a) and in the other it was a short video sequence (Figure 1b) showing a non-rigid change of expression. The second or "target" image was always a single still image.

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Similar matching tasks have been used to study many aspects of object (e.g. Kourtzi & Shiffrar, 1997; Sekular & Palmer, 1992) and face perception (e.g. Haxby et al., 1995; see Haxby, Hoffman, & Gobbini, 2000 for a review). Importantly, performance in such matching tasks is thought to be mediated by information established and maintained in temporary or working memory (e.g., Baddeley, 1986; Courtney, et al., 1996; Goldman-Rakic, 1999; Grady et al., 1998; , Miller, Erikson, & Desimone, 1996). Our interest in non-rigid motion in this paradigm then, is not whether it can help you to remember a previously seen face, with reference to long term memory, but in whether it affects your ability to match recently seen, and presumably currently active, versions of a prime and target face (FOOTNOTE 1).

Our prediction was that the dynamic primes would lead to better performance than the static primes. Why should we expected such a dynamic advantage? More specifically, why would we expect that a matching task, rather than old/new task, could successfully demonstrate such an advantage?

In one sense, a dynamic advantage could be predicted purely on ecological grounds. That is, in the real-world, faces move. If we believe that a task engages face processing mechanisms, as opposed to say, picture processing mechanisms (e.g., Bruce, 1982), then providing stimuli that are more like the "real-thing", might well be expected to show some performance advantage. Such an ecological motivation is surely one of the main driving forces behind previous studies that have employed moving rather than static images of faces (e.g., Bruce & Valentine, 1988; Knight & Johnston, 1997; Lander, et al., 1999; Pike et al., 1997; Schiff et al., 1986).

However, one might also predict a dynamic advantage due to the fact that moving primes deliver more task-relevant information than the static primes. That is, motion can make available a whole range of views of an object in a coherent, meaningful sequence. Moreover, such a sequence can be delivered to the visual system in a very short space of time. As we might reasonably assume that “more” is better than “less” information in this context, then we might also reasonably predict some form of dynamic performance advantage.

How might the visual system make use of the additional information provided by a dynamic sequence? Our working hypothesis is that objects in motion give rise to fundamentally different forms of representation than objects that neither have nor imply motion. Freyd (1987), coined the term “dynamic mental representations”, to describe such mental constructs. Using evidence from representational momentum (Freyd & Finke, 1984; Hubbard, 1995) and other forms of memory distortions (e.g. Boundary Extension, Intraub & Richardson, 1988), Freyd (1987;1993) has argued that the visual system might seek to maintain precise information about the way an object moves or changes. This could be achieved in a representational structure that contains temporal as well as spatial dimensions. She argued that such dynamic mental representations would be highly adaptive in a world in which we are constantly required to react to, and often anticipate, the behavior of other moving objects.

More recently, Kourtzi & Nakayama (in press) have proposed a similar distinction between static and dynamic object representations. They found that moving, novel objects could be primed across image transformations, such as mirror reversals and changes in size, but not across temporal delays exceeding more than a few seconds. The opposite pattern was observed for objects presented statically. They suggest the a static object system might exist to mediate long-term object recognition processes while a dynamic, motion-based system would be useful to continuously update information about objects for visual guidance of action.

Importantly, both in the studies of Kourtzi & Nakayama (in press) and the work of Freyd and her colleagues (e.g., Freyd & Johnson, 1987), the effects associated with moving stimuli have been shown to occur over very brief time intervals, on the order of a few seconds at most. This time-dependence suggests that tasks designed to probe relatively short-term representations might be better suited for exploring object dynamics than tasks aimed at long-term, more permanent representations (see also Freyd, 1983). Thus, the current matching task, with an prime-target SOA of less than a second, should be well suited for exploring facial dynamics.

The aim of the current work is not, however, to try to prove that dynamic mental representations exist, or even to suggest that they are the only mechanism that could account for potential dynamic matching advantages. Rather, the goal of this work is to first establish whether some form of performance difference between dynamic and static stimuli can be measured within the context of a face matching task. The concept of dynamic mental representations was introduced simply to motivate our general interest in dynamic objects, and to provide a rationale for the shift from old/new recognition tasks towards face matching. In the General Discussion we return to the broader issue of representation and consider other mechanisms that could underlie processing differences between dynamic and static objects.

Before that, in three experiments, we use a sequential matching task to assess whether seeing a short video clip of a smiling or frowning non-degraded, non-famous face would act as a better "prime" than a single still image of such an expression. In Experiments 1 and 2, the task was to match the identity of the people shown in the prime and target whereas Experiment 3 involved an expression matching task. As the matching decision itself was always relatively easy, the predicted difference in performance was expected in the speed with which observers would make their judgements, rather than in a difference in error rates. Our primary interest then, was in whether the speed of matching responses would vary as a function of prime type. Our main hypothesis was that moving primes would give rise to faster responses than static primes due to basic differences in information content.

EXPERIMENT 1

On each trial of this experiment, a “prime” face appeared in the middle of the screen for 540 ms. The prime face then disappeared and the screen went blank for a 300 ms interstimulus interval (ISI). Finally a “target” face appeared in the center of the screen and remained visible until the participant responded. The participant was instructed to make a “same” response if they judged that the prime face and target face belonged to the same person and a “different” response otherwise.

As shown in Figure 1, the crucial factor of image motion was manipulated by changing the nature of the prime face. For dynamic trials, the prime consisted of a 18 frame video sequence showing the onset of a smile or a frown. For static trials, the prime consisted of a single frame showing the end point of the smile or frown. The static primes were always identical to the final frame of one of the dynamic prime sequences and the duration of both types of prime was held constant at 540 ms. The second face to appear on each trial, the target face, was always a single static image. All images, both prime and target, were non-degraded, that is, they were high-quality, photographic positive, video images.

The relationship between the two faces appearing on each trial could vary across both identity and expression. These crossed factors produced four types of trial: 1) same identity/same expression, 2) same identity/different expression, 3) different identity/same expression and, 4) different identity/different expression. The inclusion of expression as a factor was motivated by our desire to examine identity matching performance across changes in non-rigid configuration and also to allow us to explore the matching of expression using an identical set of stimuli in a subsequent experiment (see Experiment 3 below).

As mentioned in the introduction, our prediction was that the dynamic primes would lead to better matching performance than the static primes. As well as reflecting the basic ease of the matching decisions itself, such a focus on speed of response, rather than error rates, follows a long tradition of explicit matching studies (e.g., Young, McWeeney, Hay, & Ellis, 1986; see Posner, 1986 for a review), where reaction time is typically the main dependent measure.

Method

Participants . Nineteen University of Oregon undergraduates (13 female and 6 male) received partial course credit for participating in this experiment. All participants had normal or corrected to normal vision and were naive as to the research questions under investigation. No participants had pre-experimental familiarity with the faces that were used as stimuli.

Stimuli. Eight short video clips of human models displaying naturalistic facial expressions were used as the stimuli in this experiment. Each clip lasted 540 ms and contained 18 discrete frames. Four models (2 female and 2 male) provided two expression sequences each, one with a positive valence (smile) and one with a negative valence (frown).

Models were filmed sitting down against a uniform white background at a standard distance of approximately 3 meters. Facial expressions were elicited using an interactive technique in which models attended to and responded to information presented on a video monitor just below the camera. This technique was designed to produce a range of expressions without requiring them to be posed or produced via the use of excessively shocking or disturbing material (Thornton, 1994).

Lighting was designed to cast a slight shadow over the left side of the face with the key light placed up and to the right of the model and a fill light, which was bounced from a reflective umbrella, being placed to the left. A backlight was used to outline the head and shoulders, providing clear separation from the background. The key and filler lights used daylight balanced, 250 watt photoflood bulbs, while the backlight was a regular 100 watt, household incandescent bulb.

After filming, individual video frames were converted to gray scale images and were apertured to reduce the influence that hair and clothing might have on identity judgments. The aperture size was an 81 pixel by 81 pixel square (approx. 3 cm x 3 cm), which when viewed at the standard distance of 60 cm used throughout these experiments, subtended 2.86° x 2.86° visual angle. The color of the background surrounding the aperture was middle gray, as was the entire screen whenever stimuli were not present.

For dynamic primes, the entire 18 frames of a video sequence was used. For static primes and all target images, the final frame of one of the sequences was presented as a still image for 540 ms. A Macintosh™ Quadra 700 with a standard 15" monitor (66.7 Hz refresh rate) was used to present the stimuli.

Design. The experiment consisted of five distinct blocks of trials, with each participant completing one training block and four experimental blocks. Each block consisted of 64 trials, half of which contained dynamic primes and half of which contained static primes. Within this motion factor, there were equal numbers of same trials and different trials. Same trials were constructed by exhaustively combining the image sequences for each model. For example, the model "male 1" contributed the following prime + target sequences: male 1 smile + male 1 smile; male 1 frown + male 1 frown; male 1 smile + male 1 frown; male 1 frown + male 1 smile. Thus, an equal number of trials contained expression matches as expression mismatches. Different trials were constructed by randomly selecting pairs of sequences from different models with the added constraints that within a block there must be equal numbers of expression match/mismatch and equal numbers of gender match/mismatch trials. The order of trials within each block was randomized separately for each participant on a block by block basis.

Procedure. Participants were seated in front of the computer screen at a standard viewing distance of 60 cm. Participants were told that each trial would involve the presentation of two faces, a prime face followed by a target face. They were instructed to pay close attention to the identity of the prime face so that they would be able to decide if the target face showed the same or a different person. Participants were told that the target face would always be a still image, but the prime face would sometimes be a short video clip (dynamic primes) and sometimes a single still frame (static primes). It was emphasized that this video/still manipulation was not relevant to the identity decision they were required to make. Likewise, it was pointed out that while the expression of the prime face and the target face would sometimes match (e.g., smile and smile) and sometimes mismatch (e.g., frown and smile), this dimension was not relevant to the task of comparing the identity of the two faces.

Participants were given 32 practice trials with an emphasis on accuracy followed by 32 practice trials with an emphasis on both speed and accuracy. Feedback was given during the second 32 practice trials in the form of a moderately loud "beep", whenever participants made an incorrect response or took longer than 800 ms to respond. When the training phase was completed, participants were informed that they would be shown another 4 blocks and that the nature of the trials, the required responses and the feedback regime would be identical to the training block. Each block consisted of 64 trials and took a little over 5 minutes to complete. The order of the trials within each block was completely randomized on a block by block basis.

Results

Table 1. presents a summary of both reaction time and accuracy data from Experiment 1. The predicted difference between dynamic and static primes was only apparent for the same identity/different expression trials. As can be seen in Figure 2, this difference took the form of a reaction time advantage for dynamic prime trials ($\underline{M}$ = 559, $\underline{SE}$ = 9), which were responded to some 20 ms faster than static prime trials

(M = 580, SE = 10), $F(1,16) = 5.34$, $MSE = 4803$, $p < 0.05$. Accuracy for same identity/different expression trials was lower than for any other type of trial, although in absolute terms it remained relatively high (M = 87, SE = .01). More importantly, there was a 2% accuracy advantage for dynamic prime trials, a trend which while not significant, argues against a speed/accuracy trade-off explanation for the observed reaction time advantage.

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Responses to the other type of same trial, same identity/same expression, were generally faster, $F(1,17) = 23.8$, $MSE = 7420$, $p < 0.001$, and more accurate, $F(1,17) = 27.18$, $MSE = .0179$, $p < 0.001$, than responses to same identity/different expression trials. However, there was no significant reaction time difference between dynamic and static prime trials for this type of trial. While there was a slight trend in the predicted direction, accuracy data showed the opposite effect, with a significant 2% advantage for static prime trials over dynamic prime trials, $F\ (1,18) = 5.32$, $MSE = .035$, $p < 0.05$.

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Analysis of trials requiring a different response, revealed no significant differences between dynamic and static primes either for reaction time or accuracy. A direct comparison of the two types of different trials revealed only one significant difference, with responses to different identity/same expression trials being generally slower than responses to different identity/different expression trials, $F = 9.24$, $MSE = 1175$, $p < 0.01$.

As the current experiment was designed with 4 repeated blocks, it was possible to examine how the pattern of results altered as participants became more familiar with the stimuli and the task. Importantly, this analysis revealed no interactions between block and type of prime. That is, the observed reaction time advantage for dynamic primes in same identity/different expression trials, was present in all four blocks and the absence of prime differences in any other type of trial was also consistent across blocks.

There were, however, clear indications that general performance improved as the experiment progressed. There was a marginal increase in accuracy across block for both types of same trial, $\underline{F}(3,51) = 2.66$, $\underline{MSE} = .009$, $\underline{p} = 0.6$, and significant reaction time decreases for both same, $\underline{F}(3,51) = 3.30$, $\underline{MSE} = 7964$, $\underline{p} < 0.05$, and different trials, $\underline{F}(3,51)= 2.91$, $\underline{MSE} = 4875$, $\underline{p} < 0.05$. There were no other main effects or interactions involving block.

As the set of facial stimuli was very small in the current experiment, an analysis of item effects was conducted to ensure that a single face was not unduly influencing the pattern of results. While some pairs of faces and some expressions did appear to be matched more quickly, the pattern of facilitation was equal for both static and dynamic images. That is, there were no interactions between type of prime and specific faces or expressions.

Discussion

The results of Experiment 1 provide some initial evidence that motion can influence the speed of matching responses. The finding of a 21 ms advantage for dynamic prime trials over static prime trials is consistent with our hypothesis that performance in this task engages representational mechanisms that capitalize on the additional information contained in the dynamic prime sequences. However, in order to better understand this apparent enhancement, what needs to be explained is why the observed advantage only appears for same identity/different expression trials.

It is perhaps not surprising that motion had no influence on trials in which the two faces showed completely different people. This suggests that in the current paradigm, motion is not affecting general levels of arousal or alertness. That is, seeing something move or change does not always increase the speed or accuracy of subsequent responses. Rather, motion appears to have some influence on the processing of a *specific* face. In Experiment 3, we further explore this notion of specificity by using the same set of stimuli, but requiring responses based on expression matching rather than identity matching.

Of the two types of trial in which the prime and the target image show the same person, only one type, same identity/different expression, showed a significant reaction time advantage. Previous memory research has found that facial motion only appears to make a difference to performance if viewing conditions are suboptimal in some way. For instance, Knight & Johnston (1996) and Lander et al. (1999) could only find recognition advantages for images that were severely degraded. In the current experiment, while all images were of equal quality, same identity/different expression trials are probably the most taxing of trials in that they require generalization across different views (i.e., expressions) of the same face. This difficulty is reflected in the overall level of speed and accuracy for this type of trial, which is lower than for any of the other three types. It is thus possible that dynamic information is more useful in same identity/different expression trials due to an increase in processing demands.

Similarly, the lack of a prime effect for the other type of same trial, same identity/same expression trials, could be related to the ease with which matching decisions can be made. This is particularly true for static trials as the target item is physically identical in all respects to the preceding prime. Such identical picture matching generally leads to very fast and very accurate responses (Bruce, 1982; Vokey & Read, 1992) which could well have overpowered potential dynamic influences. Indeed, responses to dynamic primes for this type of trial were also speeded relative to same identity/different expression trials, suggesting some advantage from the physical match between the last video frame and the target. Experiment 2 below addressed this possibility by eliminating physical match confounds.

Previous research using recognition paradigms (e.g., Christie & Bruce, 1998) has suggested that the role of motion may change as a face becomes more familiar. It is interesting to note, that in our paradigm, there appeared to be no interaction between experimental block and type of prime. That is, there was no increase or decrease in the size of the dynamic advantage as participants were repeatedly shown the same faces. As our design presented equal numbers of static and dynamic versions of every face, the observed advantage appears to arise as an immediate consequence of priming on a given trial and familiarity with a face, at least within the range studied here, does not seem to modulate the effect.

In summary, the results of Experiment 1 seem to be consistent with the idea that motion can lead to a representational advantage for immediate matching, at least when the match involves some form of generalization across successive views of the same face. In Experiment 2 we provide a further test of this idea before going on to examine whether motion can still influence processing of a face when the task is directed away from the representations underlying identity of a face and on to the more abstract representation of expressions.

EXPERIMENT 2

In Experiment 1 there were some trials in which the prime and target images were physically identical. We speculated that on such trials, picture matching rather than face processing might dominate performance (Bruce, 1982). Such physical matching might explain why same identity/same expression trials (in which prime and target were always identical) failed to show any influence of prime motion, while same identity/different expression trials (in which the prime and target were always physically different) produced a dynamic advantage. To eliminate the picture matching problem, we ran a second experiment with the same design as the first except that all *target* images were now rotated 180° in the picture plane (Yin, 1969). This manipulation meant that on every trial participants had to match an upright prime image (either static or dynamic) to an inverted, static target. As generalization from upright to inverted views was required on every trial, this experiment also provides a test of the claim that motion might be most useful when a match involves some form of generalization across views of the same object. We predicted that under such conditions, both types of same trial would display reaction time advantages for dynamic over static prime trials.

In addition to removing the physical match between prime and target images and enforcing some level of generalization on every trial, the facial inversion manipulation also increases the overall difficulty of the matching task. That is, processing an upside-down face is generally harder than processing a normal face. It is thought that faces are particularly prone to inversion effects because they rely to a large extent on configurational processing (e.g., Farah, Tanaka, & Drain, 1995; Rhodes, Brake, & Atkinson, 1993; Valentine & Bruce, 1988)[1]. As previous researchers (e.g., Knight & Johnston, 1996; Lander, et al, 1999) have suggested that facial motion may be particular useful when task demands are high, we also predicted that the size of the observed dynamic advantage would increase relative to those observed in Experiment 1.

Method

Participants. Twenty four students from the University of Oregon participated in this experiment for partial course credit. All participants had normal or corrected to normal vision and were naive as to the research questions under investigation. There were 16 female and 8 male participants. No participants had taken part in Experiment 1 and none had pre-experimental familiarity with the faces that were used as stimuli.

Stimuli & Design. The equipment, stimuli and basic design of this experiment were identical to those used in Experiment 1. The only change was that in Experiment 2, all target images were rotated by 180° in the picture plane, that is, they were shown upside-down.

Procedure. The basic training and testing procedures were also identical to Experiment 1. Participants were shown 4 blocks of experimental trials, each consisting of 64 trials. Hand of response was counterbalanced across participants and as before, the order of trials within a block was completely randomized separately for each participant.

Results

Table 2. presents a summary of reaction time and accuracy data from Experiment 2. The reaction time advantage for dynamic prime images is now apparent for both types of same identity trials (see Figure 3). For same identity/ same expression trials this 17 ms dynamic ($\underline{M}$ = 560, $\underline{SE}$ = 8) over static ($\underline{M}$ = 577, $\underline{SE}$ = 8) advantage, $\underline{F}(1,23) = 5.02$, $\underline{MSE} = 5071$, $\underline{p} < .05$, was accompanied by a general drop in speed and accuracy as compared to Experiment 1. For same identity/ same expression trials, there was very little impact of target inversion on overall speed and accuracy and the 16 ms dynamic ($\underline{M}$ = 578, $\underline{SE}$ = 8) over static ($\underline{M}$ = 594, $\underline{SE}$ = 8) advantage was again highly consistent, $\underline{F}(1,23) = 6.17$, $\underline{MSE} = 3385$, $\underline{p} < .05$. As in Experiment 1, there were no reliable dynamic advantages in accuracy data for either type of same trial.

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Despite a general decrease in performance for same identity/ same expression trials, responses to these trials were still generally faster, $\underline{F}(1,23) = 7.46$, $\underline{MSE} = 5960$, $\underline{p} < .05$, and more accurate, $\underline{F}(1,23) = 11$, $\underline{MSE} = .0165$, $\underline{p} < .01$, than responses to same identity/ different expression trials. Analysis of trials requiring a different response showed that responses to different identity/ different expression trials were generally faster, $\underline{F}(1, 23) = 5.87$, $\underline{MSE} = 1671$, $\underline{p} < .05$, but not more accurate, $\underline{F}(1, 23) = .81$, $\underline{MSE} = .01$, $\underline{p} = .38$, than different identity/ same expression trials. There were no other significant effects involving different trials.

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As in Experiment 1, there was considerable evidence that overall performance improved as participants became more familiar with the task and the faces. For same trials, there was a main effect of block, both for accuracy, $F(3,66) = 3.88$, $MSE = .019$, $p < .05$, and reaction time, $F(3,66) = 5.55$, $MSE = 9206$, $p < .01$ For different trials, there was a significant main effect of block for accuracy, $F(3,66) = 10.59$, $MSE = .024$, $p < .001$, but only a marginal effect for reaction time, $F(3,66) = 2.46$, $MSE = 7400$, $p = .07$. More importantly, however, there were no interactions involving block and type of prime, suggesting that the observed dynamic advantage is not a function of familiarity. Similarly, there were no interactions between specific faces/expressions and the type of prime across any of the four types of trial.

Discussion

The results of Experiment 2 provide further evidence that moving faces and static faces can give rise to different behavioral consequences. Unlike in Experiment 1, the observed reaction time advantage for dynamic faces was present whenever the prime and target images showed the same person. The observation of this same identity effect, together with the complete absence of prime effects for different trials, also lends further support to the idea that motion may be serving to enhance person specific representations, rather than having a general alerting or arousing effect.

While the introduction of 180° rotated target faces appears to have eliminated the effects of picture matching on the same identity/ same expression trials, it did not increase the magnitude of the observed dynamic advantage. We had predicted such an increase based on previous research suggesting the influence of facial motion might be felt most strongly when task demands were high (e.g., Knight &

Johnston, 1996; Lander, et al, 1999). However, the magnitude of the dynamic advantage for same identity/ different expression trials actually shrank a little, from an initial level of 21 ms in Experiment 1 to 17 ms in Experiment 2. One possibility for the lack of an increase was simply that the matching task places an upper limit on size of observable differences between static and dynamic trials. Another possibility is that inverting the target images did not make the general task of matching that much more difficult than in Experiment 1.

As mentioned above, there is widespread agreement in the literature that rotating faces impairs our ability to use configural processing strategies. However, there is still some debate about whether observed performance decrements reflect a qualitative shift in processing (i.e., away from configural processing towards a more featured based approach) or simply a slowing down of those processes, that is, a quantitative shift (Valentine & Bruce, 1988). Behavioral and physiological evidence exists supporting both the qualitative account (e.g., Jeffreys, 1993; Sarfaty, Mills, Knaudt and Neville, 1992; Tanaka & Sengco, 1997) and the quantitative account (e.g., Perrett et al., 1988; Valentine & Bruce, 1988; Kanwisher, Tong, & Nakayama, 1998). While the fairly subtle decrements observed in Experiment 2 seem more consistent with a quantitative account, the current data cannot rule out the operation of highly efficient feature based systems.

The use of inverted target images, and the debate surrounding how such images may be processed, raises the issue of whether tasks employing inverted stimuli can really be considered measurements of “face processing”. However, in the current experiment, it is only the target images that are inverted. The static and dynamic prime images, the main focus of the study, remain correctly oriented, as in Experiment 1. Thus, even if there are questions concerning the validity of inverted images, Experiment 2 would only be reduced to comparing how dynamic versus static faces can be matched to non-face (inverted) images.

The question of what happens to moving inverted faces versus static inverted faces has been explored in the face memory literature. Knight & Johnston (1996) found no difference between the recognition of moving versus static inverted images of famous people. In contrast, Lander et al., (1999) were able to demonstrate an advantage for moving inverted faces in two experiments with a very similar design to Knight & Johnston (1996). It is not immediately clear why the results of these experiments should be so different. We hope that future studies exploring the impact of inverted prime images in the current paradigm may shed further light on this issue.

EXPERIMENT 3

In Experiments 1 & 2 we used an identity matching task to show that moving faces can speed matching responses relative to static faces. This advantage was observed whenever identity was constant across prime and target faces and picture matching was not available as an alternative strategy. This pattern of facilitation for non-degraded, non-rigid facial motion has been very hard to demonstrate using traditional long-term memory recognition tasks (e.g. Bruce & Young, 1986; Christie & Bruce, 1998). This suggests that motion may be particularly effective during the processing of the more temporary, working memory representations thought to underlie performance during matching. In this final experiment we explore whether a similar dynamic advantage can be observed for the matching dimension is shifted from facial *identity* to facial *expression*.

In Experiment 3, a “same” response was required whenever two images depicted the same facial expression rather than the same facial identity. Observers were shown exactly the same stimuli as in Experiment 1 (FOOTNOTE 3), but the mapping of responses to pairs of images was changed. That is, observers saw the same set of four trial types, namely 1) same identity/same expression, 2) same identity/different expression, 3) different identity/same expression and, 4) different identity/different expression, but were now instructed to respond "same" if the two images showed the same expression (i.e. trial types 1 and 3) and different otherwise (i.e., trial types 2 or 4).

Changing the dimension of matching from identity to expression while keeping the physical stimuli constant should provide useful evidence about the nature of the dynamic advantage observed in Experiments 1 & 2. For instance, if the same identity/ different expression trials are still the only type of trial to show a dynamic advantage (even though they now map to a "different" response), this would suggest that the effect relies heavily on some form of object specific representation. That is, an advantage will be observed whenever a prime and the target have some basic level of object correspondence (FOOTNOTE 4).

The appearance of a dynamic advantage for any other types of trial, may help to shed further light on the relationship between identity and expression processing. There is now considerable evidence, from both behavioral and neuropsychological studies to suggest that facial identity and facial expression processing take place separately and in parallel (e.g., Bruce & Young, 1986; Humphreys, Donnelly, & Riddoch, 1993; Young, McWeeney, Hay, & Ellis, 1986).(FOOTNOTE 5). Do these systems process information in similar ways? Experiments 1 & 2 suggest that during the matching of identity, motion is recruited when some form of generalization is required. When matching expression, is it possible that the need to generalize across identity leds to a dynamic advantage? A direct analogy would predict that such an advantage would appear for different identity/same expression trials.

Finally, a failure to find any difference between static and dynamic primes while matching facial expression would suggest that the previously observed advantages reflect an interaction between object specific representations and the nature of the specific matching task.

Method

Participants. Thirty six students from the University of Oregon participated in this experiment for partial course credit. All participants had normal or corrected to normal vision and were naive as to the research questions under investigation. There were 25 female and 11 male participants. No participant had taken part in Experiment 1 or 2 and none had pre-experimental familiarity with the faces that were used as stimuli.

Stimuli & Design. The equipment, stimuli and basic design of this experiment were identical to those used in Experiment 1. The only difference was in the response mapping. Specifically, participants were told to match the depicted expression shown on the prime and target faces rather than the identity. Thus they were told to respond "same" to same identity/same expression trials and different identity/same expression trials and to respond "different" to same identity/different expression trials and different identity/different expression trials.

Procedure. The basic training and testing procedures were also identical to Experiment 1. In total, participants were shown 4 blocks of experimental trials, each consisting of 64 trials. Hand of response was counterbalanced across participants and as before, the order of trials within a block was completely randomized separately for each participant.

Results

Table 3 presents a summary of reaction time and accuracy data. Unlike in Experiments 1 & 2 there was no overall reaction time difference between dynamic and static primes for any of the four types of trial. Examination of different identity/same expression trials, however, does reveal a 17 ms trend in the direction of a dynamic advantage. While this trend was non-significant, $F(1, 28) = 1.78$, $MSE = 10673$, $p = .19$, it must be evaluated in the context of significant prime type x identity x expression interaction, $F(3, 84) = 4.41$, $MSE = 728291$, $p < .01$. Examination of this effect revealed that for two out of the possible eight prime images, dynamic responses were considerably faster than static responses ($M = 76$ ms). The remaining six prime sequences showed a small trend in the opposite direction ($M = 8$ ms). Such item effects were not present in Experiments 1 & 2. Accuracy data for different identity/same expression trials showed a consistent effect of prime, however, static images (M = 84%, SE = 2) led to more accurate responses than dynamic images (M = 80%, SE = 2), $F(1, 35) = 4.67$, $MSE = 3.2$, $p < .05$.

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INSERT TABLE 3 ABOUT HERE

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Responses to the other type of same trial, same identity/same expression, were both faster, $F(1,35) = 74.6$, $MSE = 5044$, $p < .001$, and more accurate, $F(1,35) = 65.8$, $MSE = 2.7$, $p < .001$, than responses to different identity/same expression trials. This difference between the two types of same trial was also found in Experiment 1, and almost certainly reflects the contribution of identical picture matching. Consistent with this picture matching explanation, responses to static primes were some 3% more accurate than dynamic primes for same identity/same expression trials, $F(1,35) = 4.32$, $MSE = 2.1$, $p <= .05$. While there were also prime x identity, $F(3,105) = 7.14$, $MSE = 1.6$, $p < .001$, prime x expression, $F(1,35) = 12.77$, $MSE = 2.0$, $p < .01$, and prime x identity x expression, $F(1,105) = 8.39$, $MSE = 1.5$, $p < .001$, interactions, all of these effects reflected changes in the magnitude of the static advantage, rather than the appearance of an item specific dynamic advantage. More specifically, there were no instances were dynamic primes led to more accurate responses. Analysis of the reaction time data for same identity/same expression trials, revealed no main effects or interactions involving type of prime.

Analysis of different responses revealed no reaction time effects based on the type of prime, either for same identity/different expression or different identity/different expression trials. Accuracy data for same identity/different expression trials did show a sensitivity to the type of prime, but again this reflected an advantage for static (M = 91% SE = 1.7) over dynamic (M = 88% SE = 1.9) primes, $F(1,35) = 5.89$, $MSE = 2.0$, $p < .05$. There was also a marginal prime x identity x expression interaction, $F(3,105) = 2.68$, $MSE = 1.6$, $p = .051$, with one particular prime image showing a larger than average static advantage. Accuracy data for different identify/different expression trials showed no main effect of prime, but there was again an item effect, with only one of eight prime images showing a strong dynamic advantage, $F(3,105) = 3.47$, $MSE = 1.9$, $p < .05$. A direct comparison between the two types of different trial revealed no significant differences either in terms of reaction time or accuracy.

Overall, responses on trials with smiling prime images were faster and more accurate than responses with frowning prime trials. While this pattern may have been influenced by the item specific effects mentioned above, Table 4 illustrates that this smiling advantage was highly consistent, appearing even for trial types in which such item effects were completely absent. There was only one instance of a prime x expression interaction (accuracy data for same identity/same expression trials) and this took the form of a static advantage, suggesting that motion has little overall effect on this smiling face advantage.

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INSERT TABLE 4 ABOUT HERE

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Finally, as in Experiments 1 & 2 there were consistent learning effects which did not interact with type of prime. Specifically, there were main effects of block for same trials, both for reaction time, $F(3,105) = 6.39$, $MSE = 10157$, $p < .001$, and accuracy, $F(3,105) = 3.5$, $MSE = 1.1$, $p < .05$. Similarly, responses to different trials showed main effects of block for reaction time, $F(3,105) = 7.2$, $MSE = 13573$, $p < .001$, and accuracy, $F(3,105) = 3.37$, $MSE = 1.7$, $p < .05$.

Discussion

In Experiment 3, we used exactly the same set of stimuli and organization of trials but changed the nature of the matching task from identity to expression. This task manipulation appears to have eliminated the consistent dynamic advantage found in Experiments 1 & 2. When there were consistent differences between static and dynamic prime images in the current experiment, these generally took the form of a static advantage.

An important implication of this experiment is that the appearance of a dynamic advantage in face processing appears to be sensitive to both stimulus characteristics (i.e., objects must match) and task demands (i.e., observers must be matching the objects, not features of the objects). Alternatively, the lack of a dynamic advantage could reflect some fundamental difference in information processing within the expression and identity processing streams (Bruce & Young, 1986). However, given the small set of stimuli used in the current experiment and the appearance of a number of item effects, these conclusion can only be offered as initial impressions. Further studies, particularly with larger sets of stimuli, will be required before the role of motion in expression processing can be more fully understood.

Even given the appearance of item effects, however, one clear pattern that did emerge was a striking difference in performance between smiling and frowning faces (see Table 4). This happy face advantage has been noted frequently in the face literature (e.g., Calder et al., 1997; Ekman et al., 1982; Kiouac and Doré, 1983; Ladavas et al., 1980; Kirita & Endo, 1995). A number of explanations have been put forward to explain this phenomenon, including changes in transmission rates for information at different spatial scales (i.e., smiles are defined in lower spatial frequencies, frowns in higher spatial frequencies) and differences in processing mode (i.e., smiles engage holistic processing, frowns analytic processing), but as yet there is no definitive answer (see Kirita & Endo, 1995). The current work does little but confirm the existence of this happy face advantage, although clearly our results suggest that the addition of motion does little to add or subtract from the basic effect.

GENERAL DISCUSSION

In a series of three experiments, we used an immediate matching task to demonstrate that responses to human faces can be facilitated by the presence of motion. This facilitation takes the form of a reaction time advantage for moving over static prime images and was observed for identity comparisons whenever generalization across expression (Experiment 1) or view (Experiment 2) was required. Using identical stimuli, we did not find a similar advantage for expression matching (Experiment 3). It is interesting to note that motion did not provide a general alerting or arousing advantage, but rather facilitated performance only when the prime and target images mapped on to the same basic object (i.e., a particular person) and the task was specifically focused on this identity relationship.

The identity advantage observed in Experiments 1 and 2 represents the first demonstration of a reliable difference between dynamic and static images of non-degraded, expressive faces. Previous attempts, using similar non-rigid motion sequences, were unable to find dynamic/static differences unless the stimuli were degraded images of famous faces (e.g., Bruce & Valentine, 1988; Christie & Bruce, 1998; Knight & Johnston, 1996; Lander, Christie & Bruce, 1999). We suggest that the success of the current approach lies in shifting the nature of the task from face recognition to face matching. While the observed advantage is admittedly rather modest (i.e., a speed difference of around 20 ms), we believe that future studies that retain the shift of focus from recognition to matching will be able to provide new insights into the role of facial dynamics.

As discussed in the Introduction, we believe the shift in tasks is important in the current context because matching places more emphasis on working memory representations than on the long-term representations typically thought to underlie old/new recognition performance. However, we do not mean to imply that dynamics are completely irrelevant for long-term representations. Patterns of "characteristic motion" associated with a particular individual can clearly influence identification performance (e.g., Hill & Johnston, 2001; Knappmeyer, Thornton, & Bülthoff, 2001; Lander, Christie & Bruce, 1998). The need for such patterns to develop over time, means they can only be explored by tasks designed to probe long-term memory. Indeed, we cannot completely rule out the contribution of such long-term effects in the current studies. That is, participants were given repeated exposure to the same four faces. However, the absence of prime x block interactions, suggests that more permanent representations of the four model faces are not exerting a significant influence on the matching performance. That is, effects of characteristic motion, such as those suggested by Christie & Bruce (1998), might have been expected to produce some modulation of the dynamic advantage as the experiment progressed. As the size of the effect did not significantly vary across block, there is little evidence for the influence of such familiarity effects in the current set of data (FOOTNOTE 6).

Rather than patterns of characteristic motion, the current dynamic advantage probably reflects what Lander & Bruce (2000) called the "generalized benefit" of viewing moving faces. That is, a direct representational advantage due to an increase in task-relevant information – multiple views in a coherent, timed sequence – relative to viewing static images. Following the work of Freyd (e.g., 1987) and Kourtzi & Nakayama (in press), we argue that such additional information may be captured in short-lived, "dynamic representations". The primary role of such representations is thought to be the visual guidance of on-going actions, and this, together with the brief temporal range over which they have been found to operate, suggests the involvement of working, rather than long-term, memory systems.

While the current findings are clearly consistent with this notion of dynamic representations, they do not, however, provide direct evidence that such mechanisms are responsible for the observed performance advantages. What other mechanisms might the visual system employ to take advantage of the additional information in the dynamic primes?

One possibility is that motion could link the various views contained in a dynamic prime via a generic temporal association mechanism. Influential physiological studies by Miyashita (1988;1993) have shown that individual neurons in primate temporal lobes can change their selectivity to respond to initially non-preferred images if these images frequently appear in close temporal proximity to other preferred stimuli. Inspired by these findings, Wallis & Bülthoff (2001) and Wallis (in press) have shown that human performance on face discrimination and matching tasks can also be affected by the spatio-temporal association of views during learning. Other recent computational (e.g., Edelman & Weinshall, 1991; Foldiak, 1991; Wallis & Rolls, 1997) and behavioral (e.g., Sinha & Poggio, 1996; Stone, 1998; Stone & Harper, 1999; Wallis, 1998) studies also indicate that temporal correlations, such as those associated with motion, can affect the long-term representation of objects (see Wallis & Bülthoff, 1999, for a review).

Another possible way in which motion might have been used to exploit the dynamic primes is by enhancing the available structural information. That is, the extra information in the dynamic primes might give rise to better assessments of the 3D structure of the face than static primes. A similar argument has previously been made in connection with rigid rotations of the head (Pike et al., 1997). As 3-D information has been shown to improve recognition performance (e.g., Bruce & Langton, 1994; Kemp, et al., 1996) it might also have an impact in the current matching task.

Clearly, future research will be needed to more clearly establish the nature of the dynamic advantage observed with the current matching task, thus providing firmer ground for distinguish between potential mechanisms. Varying the prime-target ISI might be one useful manipulation, as any effect based on dynamic representations should disappear quite quickly as ISI increases beyond a few seconds. It would also be interesting to see if the observed matching advantages can be found with other types of motion or change, for example rigid head rotations, visible speech, or other meaningful (e.g. morphing) or non-meaningful (e.g. warping) facial deformations. A pure “temporal association” mechanism should be affected very little by the nature of the presented sequence (Miyashita, 1993). Similarly, future studies could also compare matching performance with different types of non-face objects. The pattern of results found with other biological (e.g., human, animal or plant movements) and/or non-biological (e.g., machine parts or novel, random patterns) dynamic objects, would shed light on the specificity of the current matching advantage. Such comparisons might make a useful contribution to the ongoing debate on whether faces are afforded "special" status by the visual system (e.g., Diamond & Carey, 1986; Farah et al., 2000; Gauthier & Logothetis, 2000; Gauthier & Nelson, 2001; Kanwisher, McDermott, & Chun, 1997; Yin, 1969).

Throughout this paper an assumption has been made that motion sequences might lead to performance advantages because they increase the total information provide about a face, relative to a single static image. We share the view expressed by Lander & Bruce (2000) that such additional information might include not only the extra static views contained within the motion sequence, but also purely "dynamic information" arising from a specific spatio-temporal pattern. In previous studies of facial motion (e.g., Bruce & Valentine, 1988; Lander, Christie & Bruce, 1999; Pike et al., 1997) attempts have been made to assess whether increasing static information alone, that is, in the absence of motion, would also lead to performance advantages. This is typically done by including multiple-still control conditions. In general, whenever a dynamic advantage has been found, it has not been attributable to differences in static information content (e.g., Lander, Christie & Bruce, 1998; Pike et al, 1997). In the current work we chose not to include multiple static face controls, as our matching task involved very brief, very precisely timed trials in which it would have been difficult to present additional static information in the absence of motion (FOOTNOTE 7). Clearly, this makes us unable to separately assess the effects of static and dynamic information increase without changing the nature of the task.

However, it would be possible to manipulate either duration or the coherence of the dynamic sequence. If differences in information change-over-time is at the heart of the current effect, then, at least up to some capacity limitation, we should expect to observe an increase in the performance advantage for dynamic primes as the sequence length grows. Changing the coherence of the sequence, for instance by randomizing the order of the animation frames might also shed light on the basis of the observed dynamic advantage. Lander & Bruce (2000) recently showed significantly better recognition performance for coherent versus scrambled movies of degraded famous faces, and Wallis (in press) likewise found that spatio-temporally ordered sequences, but not unordered sequences of rotating heads, could modulate susequent discrimination performance. These results are consistent with findings from representational momentum, where only coherent sequence of implied motion give rise to the typical dynamic anticipation effects (Kelly & Freyd, 1987). It would thus be interesting to see if the current matching advantage still occurs when the prime sequence consists of a random temporal sequence of images.

In conclusion, we believe the current work represents an important step forward in the study of facial motion. Shifting the emphasis away from standard long-term memory recognition paradigms towards a sequential matching task has allowed us to demonstrate a reliable difference between the processing of static and dynamic facial images. Future work will hopefully allow us to more fully explore the mechanisms that underlie these differences.

FOOTNOTES

1) While matching tasks have proven to be a very useful tool for exploring relatively temporary, and sometimes completely novel, representations of objects, the use of such a task cannot, in and of itself, exclude the influence of long-term representations. As described in more detail below, the current experiments used a small set faces that were repeatedly shown to observers. It is thus very likely that observers quickly established strong and stable representations of these faces. However, while such long-term memory representations of the faces would almost certainly be accessed during each trial, there is little reason to believe they would have a direct impact on matching performance. Observers had equal exposure to all of the faces (i.e., there were no old/new distinction or any other differences in familiarity) and each face was seen moving as often as it was seen statically. The long-term representations of each face were, therefore, never directly probed or manipulated as part of the matching task. What was manipulated was the relationship between the prime and the test image within a given trial. That is, on some trials the prime face was moving and on others it was not. The focus of matching responses was thus the currently active representation of the prime and target faces, which we claim would be maintained in working memory

2) Objects other than faces will show a similar inversion effect to the extent that they rely on configurational coding, either through the influence of expertise (Diamond & Carey, 1988) or experimental manipulation (Gauthier & Tarr, 1997; Farah et al, 1995; Rhodes et al, 1994).

3) We did not replicate Experiment 2 as it is less clear from the literature how expression processing interacts with facial inversion.

4) While a same identity/different expression match might also suggest some form of image sequence artifact (e.g., the start of the dynamic sequences might be similar

to the static targets), the results of Experiment 2, where both types of trial showed a dynamic advantage, makes this sort of explanation seem unlikely.

5) Indeed, it is possibly due to this dissociation that the role of motion during identity processing has received so little attention. Motion is clearly a vital part of expression processing , as it is for other non-identity aspects of information extraction on the face, such as visible speech (e.g., Campbell, Brooks, de Haan, & Roberts, 1996; Campbell, de Gelder, & de Haan, 1996). The discovery of separate processing systems for such non-identity information appears to have lead to the false assumption that motion cannot also be important for solving identity related tasks.

6) One way that long-term memory could be excluded would be to use completely new faces on each trial. We are currently in the process of collecting the large corpus of moving face stimuli needed for such a design.

7) For example, the only way to present a sequence of more than one static image within the space of 500 ms would be with the add of some form of inter-item mask. Without this, some form of apparent motion would almost certainly be observed, unless the speed of image presentation was greatly reduced. Such changes, or the use of spatially non-overlapping items, would almost certainly change the nature of the task.

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TABLES

Table 1.
Experiment 1: Accuracy and Reaction Time Data for all Types of Trial Organized by Type of Prime

	Prime			
	Dynamic		Static	
Type of Trial	RT[a]	%[b]	RT	%
Same-Identity/	521	94	523	96
Same-Expression	(8)	(1)	(8)	(1)
Same-Identity/	559	88	580	86
Different-Expression	(9)	(1)	(10)	(1)
Different-Identity/	591	90	594	90
Same-Expression	(7)	(2)	(7)	(1)
Different-Identity/	587	90	586	91
Different-Expression	(7)	(2)	(7)	(2)

Note. Standard Errors are in parentheses.
[a] Median RT in milliseconds.
b Percent Correct.

Table 2
Experiment 2: Accuracy and Reaction Time Data for all Types of Trial Organized by Type of Prime

	Prime			
	Dynamic		Static	
Type of Trial	RT[a]	%[b]	RT	%
Same-Identity/	560	88	577	88
Same-Expression	(8)	(1)	(8)	(2)
Same-Identity/	578	83	594	84
Different-Expression	(8)	(2)	(8)	(2)
Different-Identity/	593	82	599	85
Same-Expression	(7)	(2)	(6)	(2)
Different-Identity/	582	85	591	83
Different-Expression	(7)	(2)	(7)	(2)

Note. Standard Errors are in parentheses.
[a] Median RT in milliseconds.
b Percent Correct.

Table 3

Experiment 3: Accuracy and Reaction Time Data for all Types of Trial Organized by Type of Prime

	Prime			
	Dynamic		Static	
Type of Trial	RT[a]	%[b]	RT	%
Same-Identity/	568	90	564	93
Same-Expression	(7)	(1)	(8)	(1)
Same-Identity/	619	88	619	91
Different-Expression	(7)	(1)	(6)	(1)
Different-Identity/	617	80	630	84
Same-Expression	(9)	(2)	(9)	(2)
Different-Identity/	626	89	627	90
Different-Expression	(7)	(1)	(7)	(1)

Note. Standard Errors are in parentheses.

[a] Median RT in milliseconds.

b Percent Correct.

Table 4

Experiment 3: Accuracy and Reaction Time Data for Smiling versus Frowning Prime Image Organized by Type of Trial

	Prime					
	Frown		Smile		Difference	
Type of Trial	RT[a]	%[b]	RT	%	RT	%
Same-Identity/	620	87	512	98	***	***
Same-Expression	(7)	(1)	(5)	(1)		
Same-Identity/	664	81	575	97	***	***
Different-Expression	(6)	(1)	(5)	(1)		
Different-Identity/	697	67	550	97	***	***
Same-Expression	(9)	(2)	(6)	(2)		
Different-Identity/	675	83	577	96	***	***
Different-Expression	(7)	(1)	(5)	(1)		

Note. Standard Errors are in parentheses.

[a] Median RT in milliseconds.

b Percent Correct.

*** $p < .001$

FIGURE CAPTIONS

FIGURE 1. The face matching paradigm used in Experiments 1-3. For static prime trials (a), a single still image was continuously shown for 540 ms. For dynamic prime trials (b) an 18 frame video sequence was displayed. Each frame of this sequence had a duration of 30 ms, giving a total duration of 540 ms. In this figure only 9 frames (every second frame) have been shown. There was no temporal separation between frames and images were constantly visible during both static and dynamic primes. A short retention interval (300 ms), was then followed by a single static target image which remained visible until response. Figure 1(a) shows an example of a different identity/different expression trial and Figure 1(b), an example of a same identity/different expression trial.

FIGURE 2. Reaction time for same trials from Experiment 1, organized by type of prime.

FIGURE 3. Reaction time for same trials from Experiment 2, organized by type of prime.

FIGURE 1

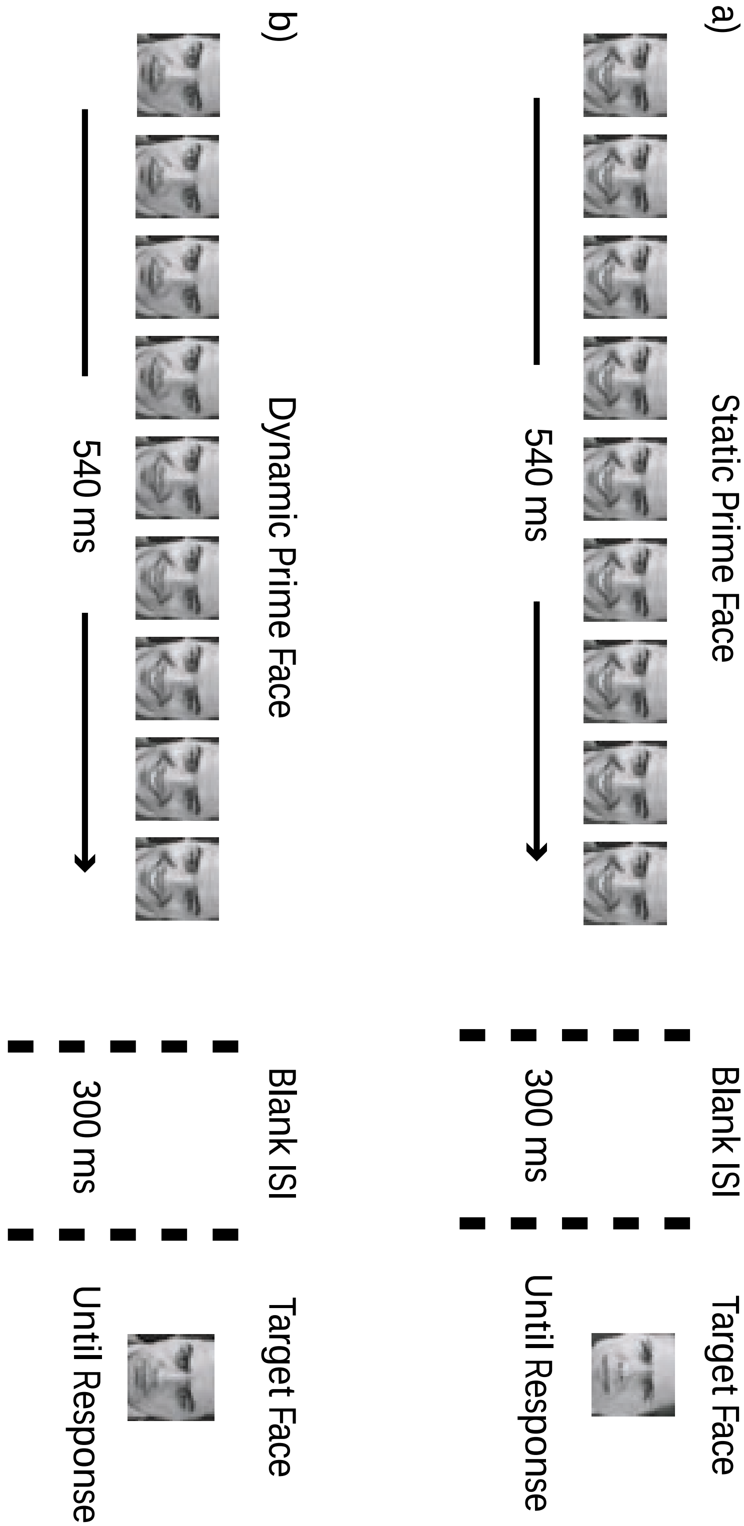

a)
Static Prime Face
540 ms
Blank ISI
300 ms
Target Face
Until Response
b)
Dynamic Prime Face
540 ms
Blank ISI
300 ms
Target Face
Until Response

FIGURE 2

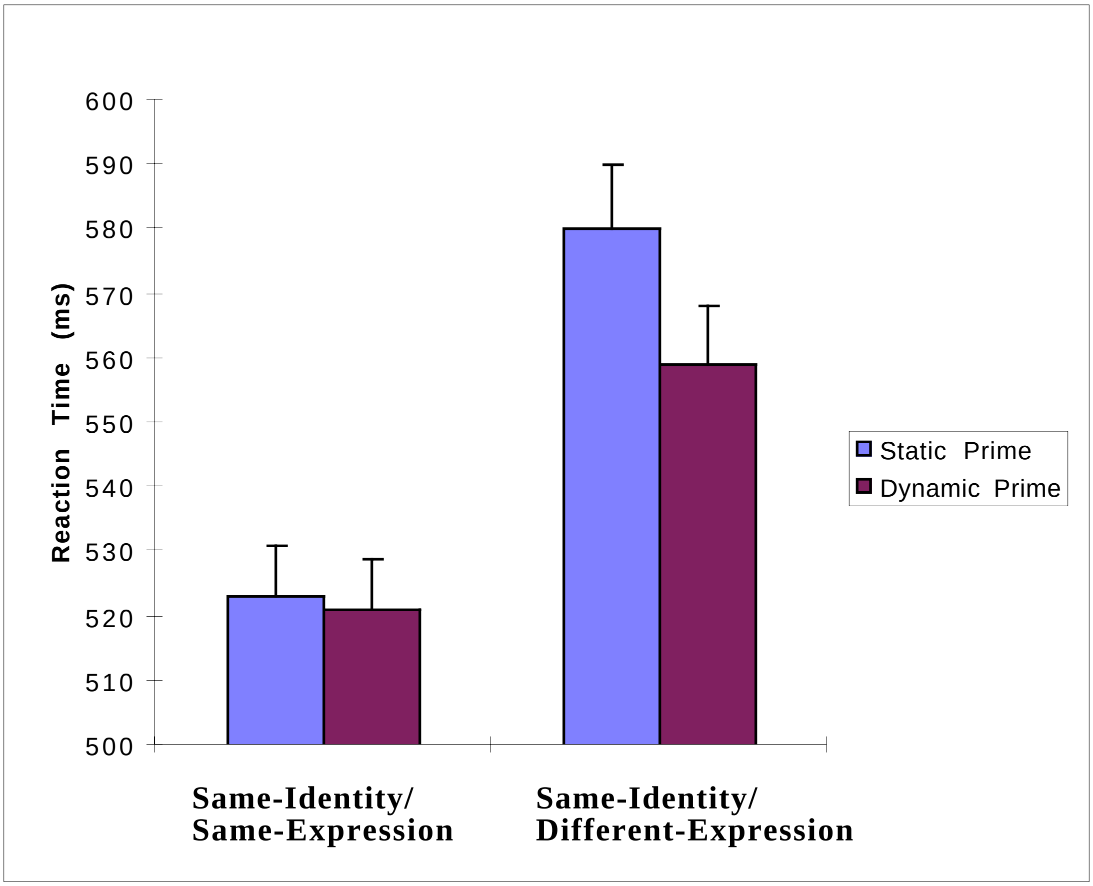
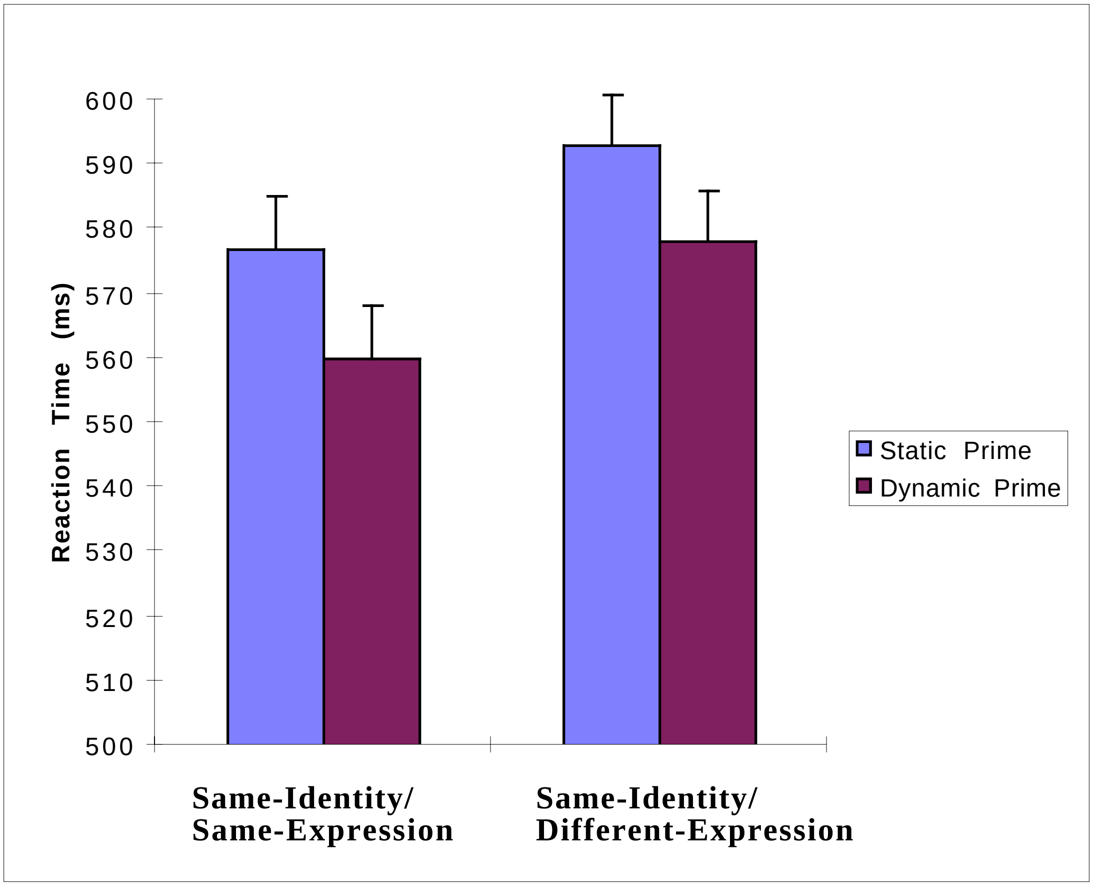

600
590
580
570
560
550
540
530
520
510
500
Reaction Time (ms)
Static Prime
Dynamic Prime
Same-Identity/
Same-Expression
Same-Identity/
Different-Expression

FIGURE 3


600
590
580
570
560
550
540
530
520
510
500
Reaction Time (ms)
Static Prime
Dynamic Prime
Same-Identity/
Same-Expression
Same-Identity/
Different-Expression