Spatial Representation of Time in Mandarin-English Bilinguals

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Introduction

Previous work has shown that time is often mapped to a spatial timeline, most likely to enhance and make communication about time, an intangible concept, easier to understand and utilize (Boroditsky, 2001; Weger & Pratt, 2008). In particular, cultural aspects such as writing and reading direction, as well as linguistic cues including spatialized time metaphors, may influence how one maps time in space. For example, we can "move meetings ahead" or "push deadlines back", both of which are expression using spatial words. Not only is time associated with certain locations in space, these mappings are so prevalent that they produce compatibility effects, such that stimuli presented in a compatible orientation to the spatiotemporal mapping are responded to faster than stimuli presented in the opposite incompatible manner. For example, when "earlier" is on the left and "later" is on the right, this is a compatible orientation with time running left to right and thus, this would result in faster response times. (Boroditsky, 2001; Fuhrman *et al.*, 2011; Miles *et al.*, 2011; Weger & Pratt, 2008)

Notably, although English speakers do not use left to right spatial time metaphors in language, evidence suggests that the reading and writing direction, as well as other graphical representations used in the culture (e.g. number lines), produce a mental timeline flowing left to right, with the left being "earlier" and the right being "later" (Boroditsky, 2001; Fuhrman *et al.*, 2011; Miles *et al.*, 2011; Santiago *et al.*, 2007; Weger & Pratt, 2008). In contrast, for Mandarin speakers, there is an additional top to bottom vertical time mapping, with "earlier" being upward and "later" being downward (Boroditsky, 2001; Fuhrman *et al*., 2011). Several aspects of Mandarin, such as the traditional vertical reading and writing direction, as well as an increased use of vertical time metaphors (using the words "up" and "down" specifically to mark time), may contribute to the way Mandarin speakers represent time in space (Fuhrman *et al.*, 2011).

These two mental timelines appear to be combined in Mandarin-English bilinguals, such that both timelines co-exist within the individual (Boroditsky *et al.*, 2011; Fuhrman *et al.*, 2011; Miles *et al.*, 2011). But what determines which timeline is used and what cues may bias a bilingual individual into using one timeline over the other? An experiment by Miles *et al.* (2011) asked Mandarin-English bilinguals to arrange photographs of two famous actors, Brad Pitt and Jet Li, in temporal order, but did not specify what orientation or axes in which to do so. They found that Brad Pitt's pictures were most often arranged left to right along a horizontal axis, and in contrast, Jet Li's pictures were most often arranged top to bottom along a vertical axis. These results suggest that the context of the pictures, more specifically, the ethnicity of the face, may have served as a cue that caused activation of one of the two existing spatiotemporal mappings in bilinguals.

In most previous studies, the main manipulation was in the spatial orientation of the response method, such that adjacent buttons on a keyboard represented "earlier" or "later" in either compatible or incompatible orientations with a typical timeline (Boroditsky *et al.*, 2011; Miles *et al.*, 2011). For example, the "earlier" button would be non-linguistically determined to be the button on the left, whereas the "later" button would be on the right. This could potentially be mapped to a compatible left to right timeline, and thus, would constitute the compatible response condition. In these studies, the visual stimuli were presented sequentially in the same location. As previously mentioned, these studies found robust compatibility effects, such that responses were faster in compatible conditions than incompatible conditions. However, a potential problem with these studies is the use of a spatially oriented response, which consequently, required a manipulation of the hands. It is possible that the robust compatibility effect is not reflective of the way people associate time with space, but rather, is simply representative of how people gesture about time. The task of moving of the hands itself may have driven the compatibility effects, and may not generalize to how people think about time, and moreover, how people may map time in space. Thus, using a different method to assess these spatiotemporal maps would be helpful in understanding where the compatibility effects come from. A different approach would be to utilize a non-spatial response and spatially oriented the stimuli. This approach would better allow one to determine if spatially oriented responses are required as a component of the previously seen compatibility effects, or if these mappings of time generalize to non-spatial tasks as well.

Therefore, if compatibility effects generalize to a non-spatial task and if the ethnicity of a face can bias bilinguals into using one mental timeline over the other, then the prediction would be to see compatibility effects for Caucasian faces along the horizontal axis only (with no difference on the vertical axis), and to see a compatibility effect along both the horizontal and vertical axis for Asian faces.

Methods

a. Design & Predictions

Face Type	Asian OR Caucasian Face			
Axis	Horizontal		Vertical	
Compatibility	Compatible	Incompatible	Compatible	Incompatible
Locations & Judgments	Earlier on left Later on right	Earlier on right Later on left	Earlier above Later below	Earlier below Later above
	Predictions			
Caucasian faces	Faster	Slower	No difference	
Asian faces	Faster	Slower	Faster	Slower

b. Materials

The experiment recruited a total of 27 Mandarin-English bilinguals. There were three portions to the experiment. The first part was an online computer-based task created and run using E-Prime.

The stimuli for this part of the experiment consisted of pictures of celebrities and famous people. A total of 50 different faces were used, ten of which were used in a practice block. All pictures were cropped to a 3-inch by 3-inch photo that included just the person's head and shoulders. For each face, there was a "middle" photo that served as the baseline and comparison photo for each trial. There was also two target photos relative to the "middle" photo—an earlier and a later picture—such that there was a total of three pictures for each face used in the experiment. Subjects would only ever see two of the three photos at any given time (always paired with the baseline photo). Of the 40 critical faces, 20 were Caucasian, and 20 were Asian, each with equal numbers of male and female faces. (See Appendix for full stimuli set)

Figure 1. Example of picture set for Caucasian face(Brad Pitt) with earlier-middle-later photos.

The offline portion of the experiment attempted to replicate the Miles *et al* (2011) experiment. This part of the experiment also used three pictures (earlier, middle, and later) per face, but only consisted of two targets: Brad Pitt and Jet Li (different photos those used during the earlier experiment). Each of the six pictures was sized to be 10-inch by 10-inch and backed with cardboard. The test board consisted of a 30-inch by 30-inch piece of cardboard.

The final component of the experiment was a computer-based background questionnaire used to determine handedness, bilingual-dominance (Dunn & Fox Tree, 2009), and general language background of each subject.

c. Procedure

1. Online Task

Before the start of the experiment, the subject was given verbal instructions as well as written instructions on the computer screen in English before proceeding to the practice block.

At the beginning of each trial, a prompt question that read "Is the second picture EARLIER?" or "Is the second picture LATER?" would appear to indicate which pictures to respond to. Using a go no-go paradigm, subjects were instructed to only respond when the answer to the question was "yes", and they would do so by pressing the center button of a button box marked only with yellow tape. The question was visible on the center of the screen for 2000msec, which was subsequently replaced by the middle (baseline) picture of one set of faces. After a 500msec delay, the second (target) picture appeared on the screen in one of four positions on the screen: (1) 1-inch above the center picture, (2) 1-inch below the center picture, (3) 2.5-inch to the left of the center picture, or (4) 2.5-inch to the right of the center picture. These four positions served to highlight the two axes: horizontal (left and right) and vertical (up and down).

The second picture to appear could have been either the "earlier" or "later" photo of that set. Subjects were asked to respond as quickly as possible after the appearance of the second image by deciding if the second picture represented the person depicted in an "earlier" or "later" point in time. If their judgment of the second picture gave a "yes" answer to the prompt question, they were asked to press the marked button, which would record their response time (RT). Otherwise, following a 2000msec delay from the appearance of the target photo, the experiment would automatically proceed to the next trial and their answer would be deemed as a "no" response. For example, if the prompt question was "Is the second picture EARLIER?" and the second picture was indeed an earlier photo of the person, then the subject should respond by pressing the marked yellow button.

The experiment, excluding the practice, was divided into four blocks. Each block consisted of 80 trials, one for each possible pair of photos in a set ("earlier" paired with middle and "later" paired with middle), presented in a pseudo-random order. The block contained two lists, List 1, which consisted of 40 items (faces) with random pairings of "earlier" or "later" photos, and List 2, which consisted of the complement pairs to items in List 1. The order in which the lists were presented in each block was counterbalanced, and the set of pictures drawn from each list was randomized. The two lists were generated to ensure that each face would only be presented once before a second presentation to prevent learning effects. Each pairing of pictures was presented four times, once in each of the four possible locations, throughout the experiment. Its complement pairing was presented in the same manner. The order of the location of the pictures was randomized throughout the experiment.

For each block, the prompt question remained the same (presented 80 times), but alternated across blocks. Thus, the order in which the two questions were presented was also counterbalanced with the order of the lists, resulting in a total of 4 experiments (with initial presentations of List 1 – "earlier" question, List 2 – "earlier" question, List 1 – "later" question, and List 2 – "later" question).

2. Offline Task

Following the conclusion of the computer-based portion of the experiment, participants were presented with the 30-inch by 30-inch test board with the "middle" picture of either Jet Li or Brad Pitt attached to the center of the board (counterbalanced across subjects). The board was either presented lying flat on the table (horizontal) or standing up in front of the computer screen (vertical), also counterbalanced across subjects. (This physical orientation of the test board was an addition to the attempt to replicate Miles *et al.* (2011).) Subjects were then handed the two remaining pictures (ie. the "earlier" and the "later" pictures) for the face attached to the board and asked to arrange the pictures in a temporal sequence (without moving the center picture). No hints regarding the direction or correct orientation to arrange the pictures were given. This procedure was repeated for the second face.

d. Data Coding

1. Online Task

Responses were coded for accuracy such that "yes" trials were matched with a button press and "no" trials were matched with a null response, as well as for compatibility, such that the presentation of pictures were either congruous with the typical timeline (earlier on the left or top, and later on the right or bottom) or non-congruous (later on the right or top, and earlier on the right or bottom).

2. Offline Task

The orientation in which the board was presented (horizontally flat on the table or vertically upright, perpendicular to the tabletop), the first face presented (Brad Pitt or Jet Li) and the direction that the subject arranged the sequence of pictures (left to right, top to bottom or vice versa) was recorded for both sets of pictures.

Results

a. Online Task

Two participants were excluded from analysis due to low accuracy (less than 80%), and one item was also excluded for low accuracy (less than 80%). The excluded item consisted of pictures of Selina Ren (Asian face), whose selected pictures may not have been sufficiently different to easily differentiate between "earlier" and "later" pictures. Subsequent analysis was only performed on trials that required a button press ("yes" response), thus recording a response time (RT). Incorrect responses to the task (no button press when one required), as well as RTs more than three standard deviations from each subject's mean response time were also removed. This resulted in an overall removal of 8.6% of the data, with 3.7% due to outliers, and 4.9% due to inaccuracy.

Mean RTs were first compared on a three-way repeated-measures ANOVA (face type × axis × compatibility), which revealed no significant main effects or two-way interactions. The three-way interaction by subject was non-significant, ($F(1,184) = 1.58$, $p = 0.21$). The items analysis (between subjects on face type, within subjects on axis × compatibility) revealed an almost significant two-way interaction of face type × axis, ($F(1,37) = 4.07$, $p = 0.051$), such that RTs for Caucasian faces were faster on the horizontal axis ($M = 738.08$ msec) than the vertical axis ($M = 764.66$ msec), whereas there was no difference in RTs for Asian faces presented along a horizontal (M = 775. 15 msec) versus vertical axis ($M = 770.59$ msec). Post hoc t-tests confirm that there was a significant difference between axes for Caucasian faces, ($t(19) = 2.38$, $p < 0.05$), but not so for Asian faces, ($t(18) = 0.36$, $p = 0.72$).

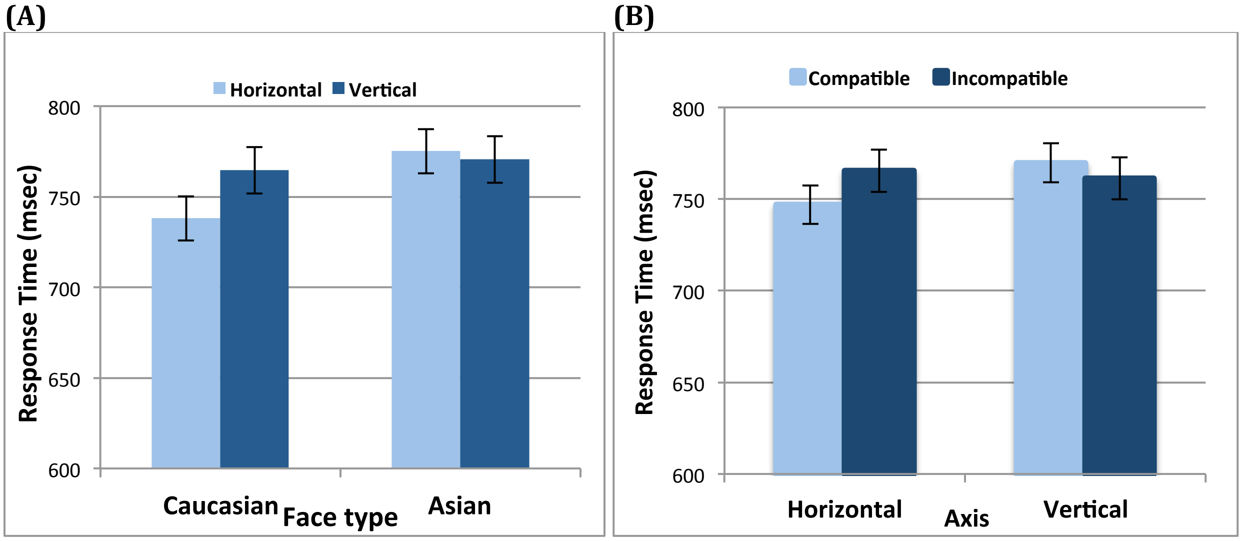

Figure 2. (**A**) Mean response time as a function of face type (Caucasian vs. Asian) and axis (horizontal vs. vertical) for Mandarin-English bilinguals. (**B**) Mean response time as a function of compatibility (compatible vs. incompatible) and axis (horizontal vs. vertical).

The three-way ANOVA by items also showed an non-significant trend of facetype, ($F(1,37) = 1.58$, $p = 0.22$), most likely due to the inherent nature of the stimuli, such that Caucasian faces had faster RTs ($M = 751.63$ msec) than Asian faces ($M = 772.90$ msec), as well as a non-significant trend of axis, ($F(1,37) = 1.87$, $p = 0.18$), such that responses were faster on the horizontal axis ($M = 756.23$ msec) than the vertical axis ($M = 767.47$ msec).

The items analysis also revealed an non-significant interaction of axis × compatibility, ($F(1,37) = 1.52$, $p =0.23$), such that pictures presented horizontally compatible were minutely faster ($M = 746.90$ msec) than horizontally incompatible presentations ($M = 765.31$), which aligns with previously noted compatibility effects, but in the vertical orientation, compatible presentation ($M = 769.65$ msec) were minutely slower than incompatible presentations ($M = 765.31$ msec). These differences were not statistically significant. Finally, the items analysis did not reveal a significant three-way interaction of face type × axis × compatibility, ($F(1,37) = 0.20$, $p = 0.66$).

Further analysis was conducted by breaking down axis and compatibility into "judgment" and "location". A three-way ANOVA (face type × judgment × location) by subjects revealed only a non-significant main effect of judgment (earlier or later), ($F_1(1,368) = 1.16$, $p = 0.28$), but reached significance by items, ($F_2(1,37) = 21.76$, $p < 0.05$). The items analysis also showed a non-significant main effect by face type, ($F(1,37) = 2.73$, $p = 0.11$), such that Caucasian faces ($M = 751.63$ msec) were slightly faster than Asian faces ($M = 772.90$ msec). Both these effects were mostly likely explained by the inherent nature of the stimuli, such that earlier faces were easier to differentiate (ie. childhood photo) from the baseline (ie. early adult photo) than later faces (ie. later adult photo) and by the fact that Caucasian faces, in generally, seem to be easier to differentiate than Asian faces.

There was also a non-significant trend of position, ($F(3,111) = 1.32$, $p = 0.27$), such that responses were fastest on the left ($M = 754.05$ msec) and right ($M = 758.40$ msec) positions, and slower in the up ($M = 761.67$ msec) and down ($M = 773.58$ msec) positions, which was also seen in previous ANOVA collapsing by axis and compatibility.

There was also a non-significant interaction of face type × judgment, ($F_2(1,37) = 1.97$, $p = 0.17$), such that the difference between judgments (earlier or later) on Asian faces (*diff* = 127.68 msec) was much larger than that for Caucasian faces (*diff* = 63.19 msec), which again, may be explained by the inherent nature of the stimuli (Asian later faces were most likely harder to distinguish than Caucasian later faces). Finally, this ANOVA revealed no significant three-way interaction, ($F(3,111) = 0.2436$, $p = 0.87$).

b. Offline Task (replication of Miles *et al.*, 2011)

The test board was placed in either the horizontal (parallel to the tabletop) or vertically orientation (perpendicular to the tabletop), but regardless of the placement of the test board, out of a total of twenty-five subjects, twenty-three subjects arranged Brad Pitt's pictures horizontally from left to right (92%). For Jet Li's pictures, twenty-one subjects arranged the pictures horizontally from left to right (84%), and only one subject arranged his pictures vertically from top to bottom (4%). The difference between the proportions of arrangements of the two faces was not statistically significant (Fisher's Exact Test, $p = 0.334$), indicating a failure to replicate the Miles *et al.* (2011) findings.

There were also two subjects who arranged Brad Pitt's pictures vertically from bottom to up (incompatible vertical orientation), and three subjects who arranged Jet Li's pictures from right to left (incompatible horizontal direction), which were all grouped together in an outlier category as "other".

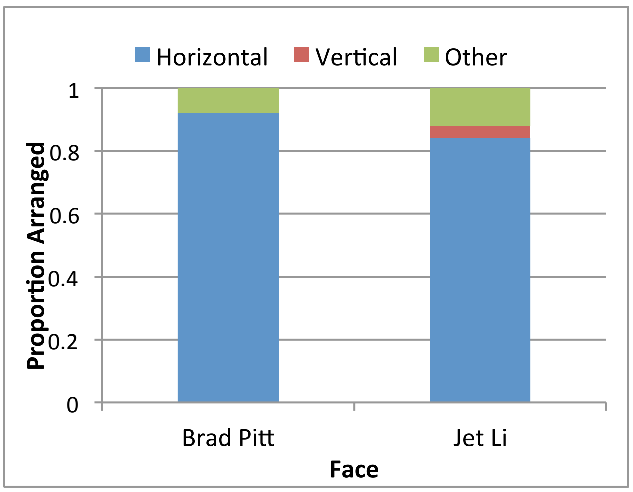

Figure 3. Proportion of horizontally vs. vertically arranged (other: incompatible orientations) pictures as a function of target face (Brad Pitt vs. Jet Li).

Discussion

The most interesting finding is that I was unable to replicate the original findings of the Miles *et al.* (2011) study. Even manipulating the orientation of the test board (in particular, by placing the board vertically) did not seem to bias subjects into arranging Jet Li's pictures from top to bottom, vertically. There are several possible explanations for my findings. First and foremost, the subjects used in the Miles *et al.* (2011) were Singaporean Mandarin-English bilinguals, whereas my subject pool consisted of American Mandarin-English bilinguals. It is possible that in Singapore, where there are likely more uses of vertically written language than in the States, there were factors other than context of pictures that were influencing subjects to arrange pictures of Asian context (Jet Li) vertically rather than horizontally. Thus, the verticality effects seen in the Miles *et al.* (2011) experiment may be due to influences from factors such as writing direction, and familiarity with vertically oriented language, rather than just the ethnicity of the presented faces. Another possibility is that there were differences in the instructions given for the experiment. In Miles *et al.* (2011), subjects were not tested on an experiment prior to performing the picture arranging task, but the subjects in the current study performed this picture arranging task after an experiment that manipulated spatial orientations. Moreover, these subjects signed consent forms and read instructions in English running left to right, which may have biased their natural spatiotemporal mappings, causing them to all arrange a temporal sequence of pictures in the same manner.

Additionally, although this study hoped to replicate previously seen compatibility effects using a non-spatially oriented response, unfortunately, there were no significant differences by compatibility. A possibility for this finding is that manipulation of the hands is actually a component of the compatibility effect found in previous studies (Boroditsky, 2001; Fuhrman *et al.*, 2011; Miles *et al.*, 2011). By using a non-spatially oriented response method, which did not require movement of the hands through space, these effects disappeared because the spatially movement of the hands may have been driving the compatibility effects seen in previous studies. It is possible that moving the hands to respond in previous studies acted as a form of gesturing about time, which in turn, was producing the compatibility effects, instead of the mental timelines that bilinguals possess. This would make it difficult to generalize the compatibility effect to how bilinguals may think about time in space.

When collapsing across compatibility, the two-way interaction of face type × axis suggests that although the compatibility effects may have a strong connection to the movement of the hands, the axes effect may not be linked to a spatially oriented response. The interaction indicates that Caucasian faces, which potentially activated the horizontal axis associated with English, showed faster responses when these faces were presented on the corresponding horizontal axis as compared to these faces presented on a vertical axis. In contrast, Asian faces, which would potentially activate both spatial timelines associated with Mandarin, showed no difference in response time, regardless of the axes along which the faces were presented. These findings seem to support the idea that the faces were only activating the contextually relevant mental timelines, and thus produced a "compatibility effect by axis" of presentation. On the other hand, the context of the Asian faces activated both the vertical and horizontal axes associated with Mandarin, and thus, showed no such "compatibility effect" as either axes would have been compatible with the activated timeline. These findings suggest that the face type (ethnicity) did indeed serve as some type of cue for bilinguals to activate a specific timeline.

Conclusions

The finding that Caucasian faces seem to activate a contextually relevant horizontal axis, while Asian faces appear to activate two relevant axes—both the horizontal and vertical axis—suggest that the ethnicity of a face seems to serve as cue for Mandarin-English bilinguals to determine which mental timeline they should reference. In particular, this effect was relatively robust even in the absence of a spatially oriented response. In contrast, the compatibility effect (earlier and later judgments in corresponding locations, with earlier on the left or above, and later on the right or below) was absent from the study, which suggests that the effect is strongly linked to the physical movement of the hands, possibly attributable to the role of gestures in language.

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Appendix

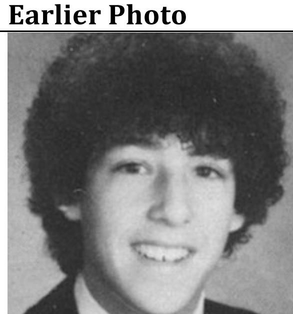
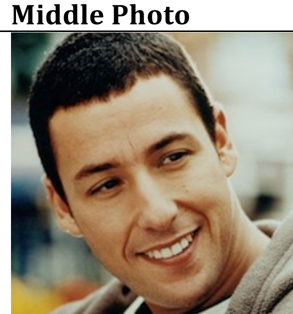
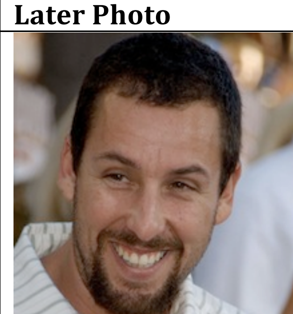
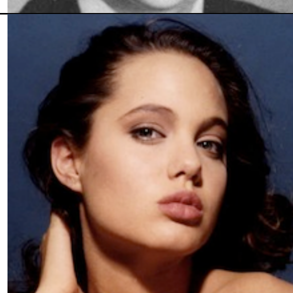
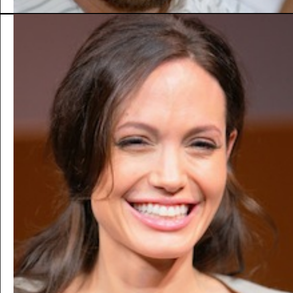
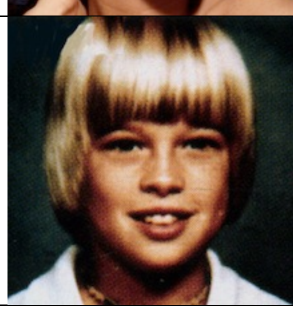
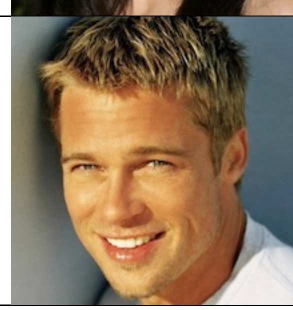
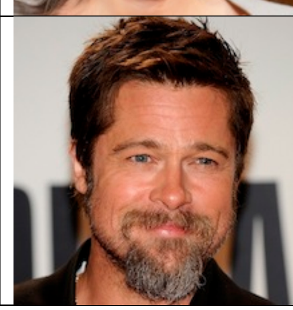
a. Previous Versions of the Experiment

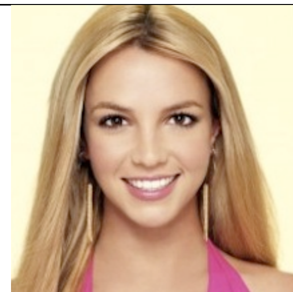
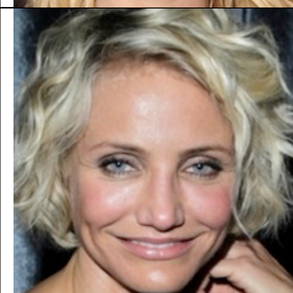
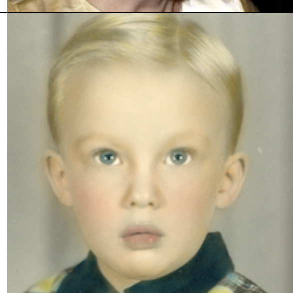
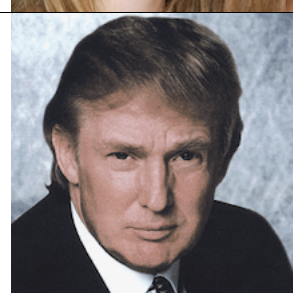
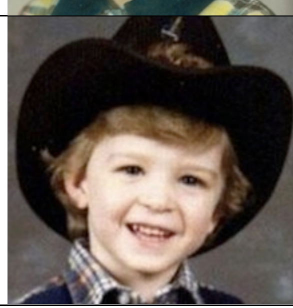
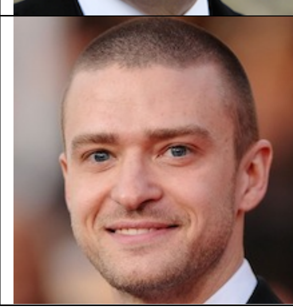
The original experiment did not utilize a go no-go paradigm, but instead employed a voicekey in place of the button press and also, did not use a prompt question, but instead asked subjects to indicate their judgment for every set of presented pictures by verbalizing "earlier" or "later". Each trial began with a fixation cross. After a 1000msec delay, the first picture of a given pair (either the earlier or later picture) would overlay the fixation cross in the center of the screen. After a 500msec delay, the second picture would appear in one of the four locations (see Methods), and subjects were asked to respond as quickly as possible upon seeing the second picture.

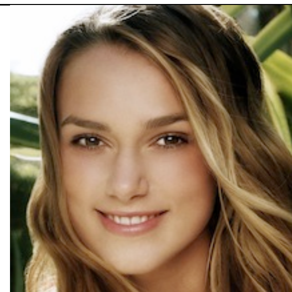
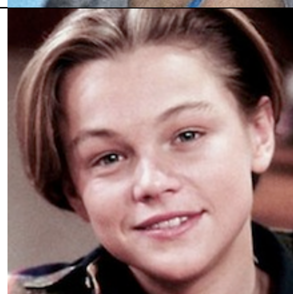
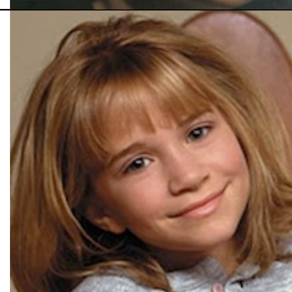
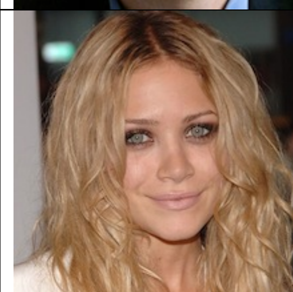
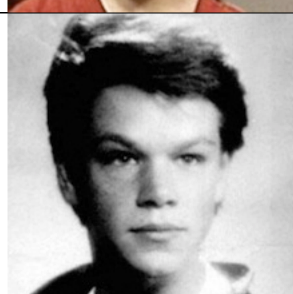
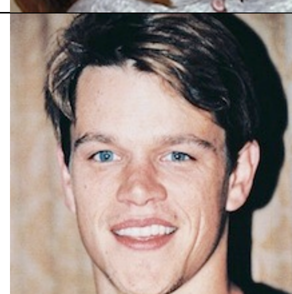
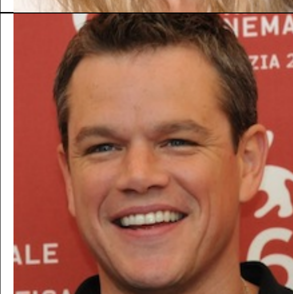
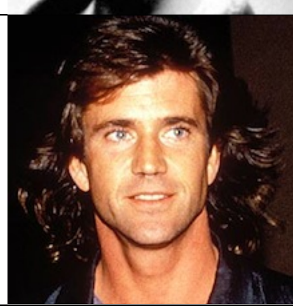
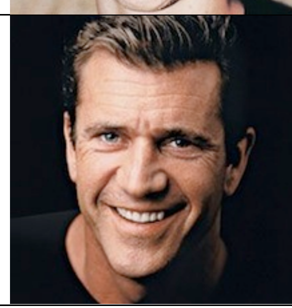
A second modified version of this experiment hoped to eliminate differences in RT due to attentional differences (where subjects happened to be attending when the second picture appeared) and did so by adding the presentation of an asterisk for 500msec in the corresponding location in which the second picture would subsequently replace.

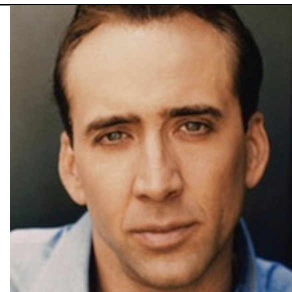
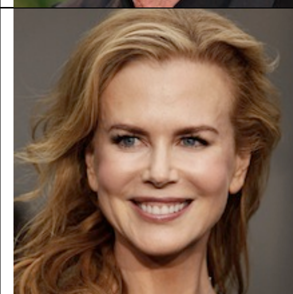
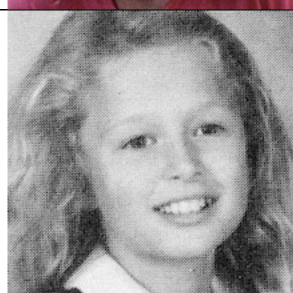
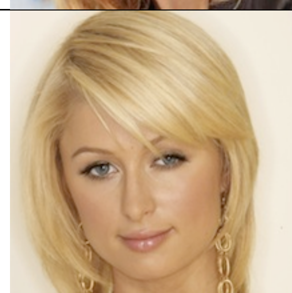
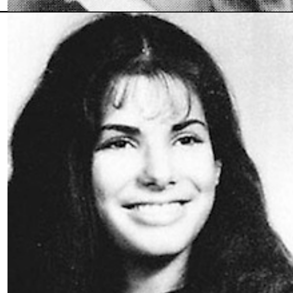
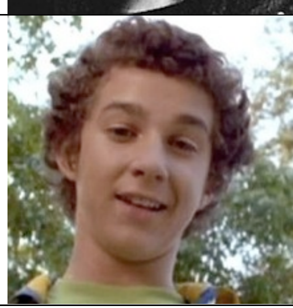
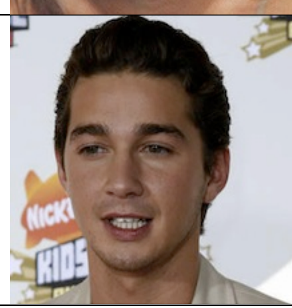
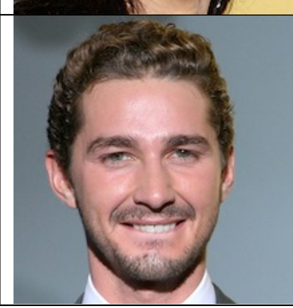
Both of these versions were divided into 8 blocks, with 60 pairs of pictures presented in each block, for a total of 480 presentations. (A practice block consisted of 10 sets of pictures not used in the rest of the experiment). Twenty filler faces used in the first two versions were removed from the final version of the experiment to reduce the duration of the experiment, and because the critical faces served as fillers for each other in the go no-go paradigm.

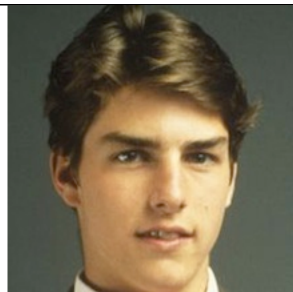
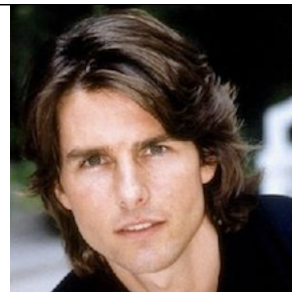
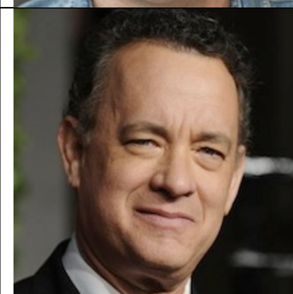
b. Stimuli

Face	**Earlier Photo**	**Middle Photo**	**Later Photo**
Adam Sandler			
Angelina Jolie			
Brad Pitt			

Britney Spears			
Cameron Diaz			
Dakota Fanning			
Donald Trump			
Justin Timberlake			

Keira Knightley			
Leonardo Dicaprio			
Mary-Kate Olsen			
Matt Damon			
Mel Gibson			

Nicholas Cage			
Nicole Kidman			
Paris Hilton			
Sandra Bullock			
Shia LeBouf			

Tom Cruise			
Tom Hanks			
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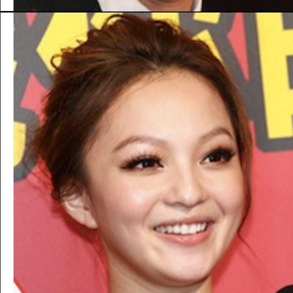
Angela Zhang			
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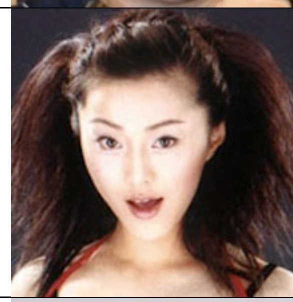
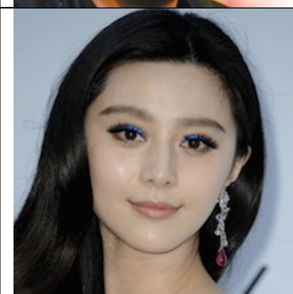
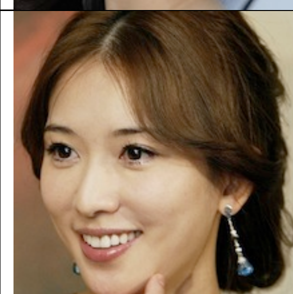
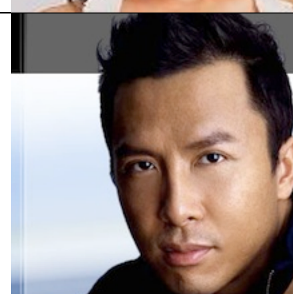
Bing-Bing Fan			
Chi-Ling Lin			
Donnie Yen			
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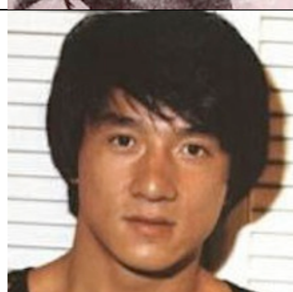
Elva Hsiao			
Li Gong			
Jackie Chan			
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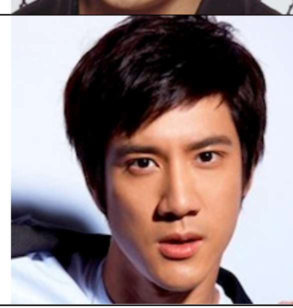
Leehom Wang			

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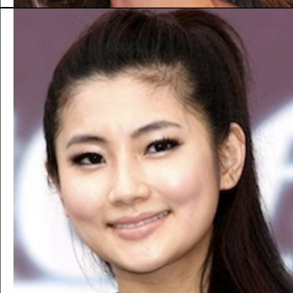
Selina Ren			
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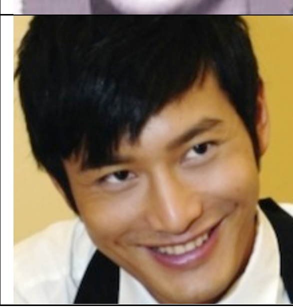
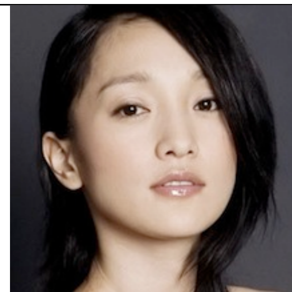
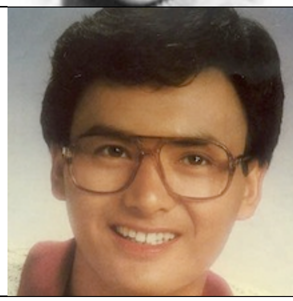
Wen Jiang			
Xiao Ming Huang			

Xun Zhou			
Yun-Fat Chow			

c. Offline Task

Face	**Earlier**	**Middle**	**Later**
Brad Pitt			
Jet Li