



Report

Continuous dynamics in the real-time perception of race

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ABSTRACT

Although the outcomes of race categorization have been studied in detail, the temporal dynamics of real-time processing of race remain elusive. We measured participants' hand movements en route to one of two race-category alternatives by recording the streaming x, y coordinates of the computer mouse. Study 1 showed that, when categorizing White and Black computer-generated faces that featurally overlapped with the opposite race, mouse trajectories showed a continuous spatial attraction toward the opposite category. Moreover, these race-atypical White and Black targets induced spatial attraction effects that had different temporal signatures. Study 2 showed that, when categorizing real faces that varied along a continuum of racial ambiguity, graded increases in ambiguity led to corresponding increases in trajectories' attraction to the opposite category and trajectories' movement complexity. These studies provide evidence for temporally dynamic competition across perceptions of race, where simultaneously and partially-active race categories continuously evolve into single categorical outcomes over time. Moreover, the findings show how different social category cues may exert different dynamic patterns of influence over the real-time processing that culminates in categorizations of others.

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Continuous dynamics in the real-time perception of race

On catching sight of another's face, it often seems as if the visual construal of race is instantaneous—something that happens in a discrete moment. This anecdotal experience is mirrored by the longstanding trend in social psychology to treat social category activation as the initial stage of person perception (Brewer, 1988; Fiske & Neuberg, 1990)—a trend that has emphasized the immediate and automatic nature of social category activation. Recent work on social categorization has primarily centered on charting the various conditions that modulate social category activation, highlighting its malleability (e.g., Blair, 2002; Macrae & Bodenhausen, 2000; Martin & Macrae, 2007). Throughout this important work, the focus has been on the products rather than process—or temporal dynamics—of social categorization (see Freeman, Ambady, Rule, & Johnson, 2008). In part, this may be due to methodological constraints: reaction times can be limited in their ability to make inferences about what sort of perceptual-cognitive processing is occurring across time—especially how this processing evolves over time.

One way to uncover the real-time processing that eventuates in ultimate categorizations is to examine perceivers' reaching arm

movements as they make their way into one of multiple response alternatives. Although motor responses are classically considered to be the end-result of a one-way route from perception → cognition → action (temporal cortex → “association cortex” → premotor areas), there is now a great deal of evidence demonstrating that motor responses are continuously directed by cognitive processing over time (e.g., Gold & Shadlen, 2001; Song & Nakayama, 2009; Spivey, Richardson, & Dale, 2008). Thus, continuous motor responses, such as the reach of an arm, may be informative as to what the perceptual system is doing across those fuzzy fractions of a second between catching sight of another's face and recognizing that person's social category memberships.

In a previous study, participants categorized the sex of typical and atypical, male and female faces by moving the computer mouse from the bottom-center of the screen to either the top-left or top-right corners, which were marked “male” and “female” (Freeman et al., 2008). Participants were asked to simply click on the correct sex category while the streaming x, y coordinates of their real-time mouse movements were recorded. When categorizing faces of atypical men and women (appearing partially like the opposite sex), participants' mouse movements were continuously attracted toward the opposite sex category on the opposite side of the screen. For instance, when categorizing an atypical target (e.g., feminized man) participants' mouse movements gravitated a bit more towards the “female” label than when categorizing a typical target (e.g., masculinized man). This is evidence that perceivers enter-

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tained simultaneously and partially-active representations of both categories (male and female), which together gradually evolved into an ultimate categorization across hundreds of milliseconds.

Importantly, these findings provide evidence for a dynamic continuity account of person construal (see Freeman et al., 2008) and show that sex categorization never discretely occurs in any single moment. It was not the case that one single category representation (e.g., male) fully activated at some instantaneous moment after the presentation of a face; nor was it the case that one single category representation transitioned from zero activation to full activation across time. Quite differently, the findings suggest that social categorization is capable of involving alternative, competing categories that are partially-active at the same time, continuously across construal. That such a continuous process underlies social categorization has been additionally suggested by event-related brain potential (ERP) evidence (Freeman, Ambady, & Holcomb, 2009).

Why would such continuously-competing category representations underlie social categorization? The answer lies in how social category representations might be implemented in a human brain. There is evidence in the cognitive and neural sciences that mental representations, as realized in the brain, are neuronal populations that contain information (e.g., “he’s White!”) through patterns of activity distributed across many neurons (Rogers & McClelland, 2004; Spivey & Dale, 2004). Neurophysiological work confirms this with regards to representations of the face (Rolls & Tovee, 1995; Sugase, Yamane, Ueno, & Kawano, 1999). Thus, modern-day models of how perceptual decisions are made predict that a race categorization, for instance, would involve continuous changes in a pattern of neuronal activity (Smith & Ratcliff, 2004; Usher & McClelland, 2003). In early moments of processing, representations of race would reflect a rough “gist” of the face. For instance, about 50% of the face’s visual information rapidly accumulates into neuronal populations as early as only 80 ms after a face’s presentation, but the remaining 50% of face information gradually accumulates over the following hundreds of milliseconds (Rolls & Tovee, 1995). Thus, representations during early moments of processing tend to be partially consistent with multiple interpretations (both White and Black) because the initial rough sketch of a face partially supports both interpretations. As the ongoing accrual of more and more face information continues, however, the pattern of neural activity gradually sharpens into an increasingly clear interpretation while other partially-active representations naturally die out. Thus, one race category (e.g., Black) can rapidly gain activation during early moments of processing, but during later portions of processing—as more face information is accumulated—an alternate category (e.g., White) can become partially activated and swing the competition its way (Freeman et al., 2008; Rogers & McClelland, 2004; Smith & Ratcliff, 2004; Spivey & Dale, 2004). This competition ensues until an ultimate race categorization is eventually settled on.

By tracking computer mouse movements, this dynamic category competition can be captured in real-time (Freeman & Ambady, *in press*; Spivey & Dale, 2004), as has been done with sex categorization (Freeman et al., 2008) and taxonomic animal classification (Dale, Kehoe, & Spivey, 2007). Here we aim to extend these findings in several ways. First, we extend our evidence for a dynamic competition across sex categorization to another social category: race. There are two prominent differences between these category dimensions that have theoretical importance for our interest in the real-time dynamics of person perception more broadly. One difference is the symmetric nature of sex and asymmetric nature of race. Specifically, perceivers are likely to routinely encounter similar amounts of men and women, and thus the functional significance of perceiving cues diagnostic of men and women should be similar. However, in most cases, perceivers are

likely to routinely encounter disproportionate amounts of White and Black individuals. Because the White category represents a cultural “default,” and White individuals are generally encountered more often than Black individuals in the US, the White category tends to be assumed if no other dimension-relevant information is provided (Smith & Zarate, 1992; Zarate & Smith, 1990). Thus, in a White-majority environment, the perceptual system may be biased towards Black-cueing features, which are ecologically salient, relative to White-cueing features (Levin, 1996). Indeed, ERP evidence has shown that attention is preferentially directed to Black targets early in processing (Ito & Urland, 2003, 2005). In the present work, we wanted to determine how more salient Black-cueing features and less salient White-cueing features influence the time-course of race categorization in potentially divergent ways.

The second important difference between dimensions of sex and race is the inherently fuzzy nature of race relative to the substantially less fuzzy nature of sex. Whereas it is rare to encounter faces that are truly sex-ambiguous—an unlikely situation usually evoking anxiety, a few laughs, or both (e.g., Saturday Night Live’s androgynous “Pat” skits)—perceivers often encounter faces that do not fit squarely into any race category at all. Interactions with mixed-race individuals, for instance, involve the perception of faces that tend to contain major physiognomic overlap between multiple traditionally-distinguished race categories. Prior research indicates that, even in instances of extreme racial ambiguity (e.g., mixed-race faces), perceivers readily resolve this ambiguity by slotting faces into traditionally-distinguished race categories (Pauker et al., 2009), particularly during rapid categorization (Peery & Bodenhausen, 2008). In the present work, we wanted to determine how this resolution of racial ambiguity is accomplished in real-time. Because perceptions of race can be fuzzy and involve different levels of ambiguity, this gave us the opportunity to examine how graded increases in the ambiguity of a social category may have corresponding graded effects on the real-time evolution of social categorization responses.

In the present work, we make use of a mouse-tracking paradigm to investigate the real-time development of race categorizations. By presenting perceivers with racially atypical or ambiguous faces, we can invoke a competition between race categories that allows us to assess the temporal dynamics in race perception more broadly. In Study 1, for precision and control, we use computer-generated White and Black faces morphed along race to be either typical or atypical. For greater breadth and generalizability, in Study 2 we use real faces that varied along a continuum of racial ambiguity, permitting an inspection of graded effects on the competition between race categories.

Study 1

We tracked mouse movements while participants categorized computer-generated faces as either White or Black. The typical condition included White and Black face stimuli whose level of race was generated at the anthropometric White and Black means. The atypical condition comprised these same White and Black stimuli, except their race was generated at a level closer to the other race. If perceiving race indeed results from continuous dynamics, the mixture of White-specifying and Black-specifying cues on atypical targets should trigger multiple partially-active race categories (White and Black) that simultaneously compete over time to gradually settle onto ultimate categorizations. This would be evidenced by a continuous attraction in participants’ hand movements toward the opposite-race category before settling into eventual responses for race-atypical faces.

Method

Participants

Twenty-six undergraduates participated for partial course credit or \$10 (self-identified race/ethnicity: 16 White, 5 Asian, 2 Black, 2 Latino, 1 Biracial).

Stimuli

To generate highly realistic faces and morph along race, we used FaceGen Modeler. This software uses a 3D morphing algorithm based on anthropometric parameters of human population (Blanz & Vetter, 1999), in which a continuum from White to Black race-category can be manipulated while holding other extraneous cues constant. For instance, Black faces are characterized by darker skin, a broader nose, and fuller lips, among other more subtle parameters, relative to White faces. This algorithm does not make assumptions about what differs between White and Black faces; rather, by averaging across many faces, parameters that emerge as reliably different between the races become incorporated into the morphing. Ten unique White faces (five male) were generated at the White mean and 10 unique Black faces (five male) were generated at the Black mean, together composing the typical condition. The 10 typical White faces were then morphed 25% toward the Black mean, and the 10 typical Black faces were then morphed 25% toward the White mean, together composing the atypical condition.

Procedure

To begin each trial, participants clicked on a “start” button located at the bottom-center of the screen. Once clicking this, a face appeared in its place. Targets were presented in a randomized order and were categorized by clicking either the “White” or “Black” label, located in the top-left and top-right corners of the screen (randomized across participants). During this process, we recorded the streaming x, y coordinates of the mouse (sampling rate ≈ 70 Hz). To ensure trajectories were on-line and capturing participants’ decision process, we encouraged participants to begin initiating movement early. As in previous research (Freeman & Ambady, 2009), if initiation time (the moment the mouse was first moved) exceeded 400 ms, a message appeared after participants made their response, encouraging them to start moving earlier on future trials even if not yet fully certain about their response. To record, process, and analyze mouse movements, we used the software package, MouseTracker, developed by the first author and freely available on the web (<http://mousetracker.jbfreeman.net>). Details about the software and a discussion of analytic techniques for mouse trajectory data can be found in Freeman and Ambady (in press).

Results

Data preprocessing

All trajectories were rescaled into a standard coordinate space (top-left: “-1, 1.5”; bottom-right: “1, 0”) and normalized into 101 time-steps using linear interpolation to permit averaging of their full length across multiple trials. For comparison, all trajectories were remapped rightward. To obtain a by-trial index of the degree to which the mouse was attracted toward the opposite-race category (indexing the simultaneous activation of that category), we computed area-under-the-curve (AUC): the area between the observed trajectory and an idealized response trajectory (a straight line between the trajectory’s start and endpoints).

Spatial attraction

The mean trajectories for typical/atypical White targets appear in Fig. 1 and those for typical/atypical Black targets appear in Fig. 2. The mean trajectory for atypical White targets showed a continuous attraction toward the “Black” response, and the mean trajec-

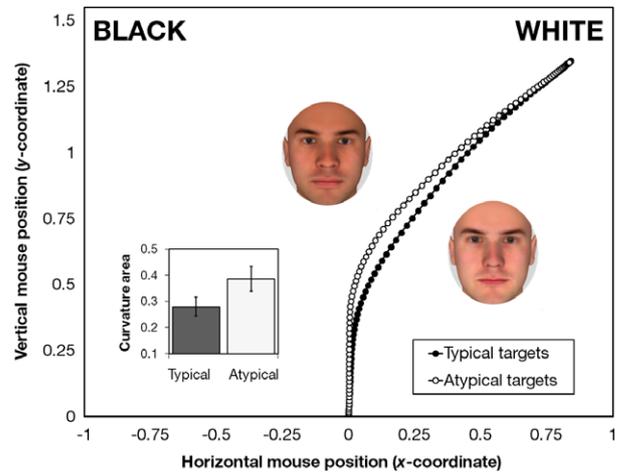


Fig. 1. Real-time mouse trajectories for atypical White faces show a continuous attraction to the “Black” response alternative (Study 1). This was statistically reliable, as indexed by AUC (bar plot). All trajectories in the figure are remapped rightward, such that the correct category is on the right and the opposite category on the left. A sample typical White face is shown on the right, next to the mean trajectory for typical White targets, and a sample atypical White face shown on the left, next to the mean trajectory for atypical White targets. On every trial, a single face was presented at the bottom-center of the screen.

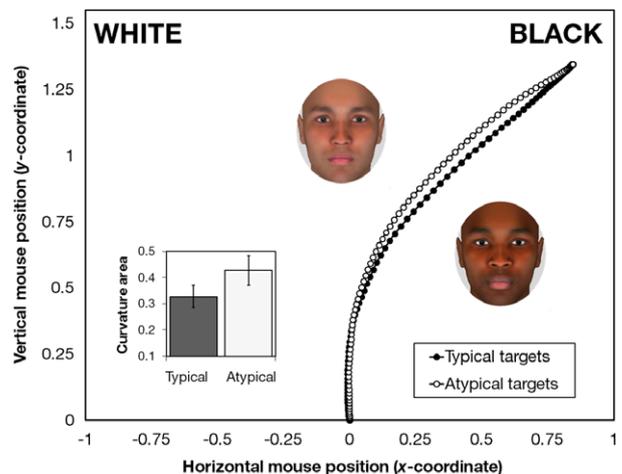


Fig. 2. Real-time mouse trajectories for atypical Black faces show a continuous attraction to the “White” response alternative (Study 1). This was statistically reliable, as indexed by AUC (bar plot). All trajectories in the figure are remapped rightward, such that the correct category is on the right and the opposite category on the left. A sample typical Black face is shown on the right, next to the mean trajectory for typical Black targets, and a sample atypical Black face shown on the left, next to the mean trajectory for atypical Black targets. On every trial, a single face was presented at the bottom-center of the screen.

tory for atypical Black targets showed a continuous attraction toward the “White” response. To assess these statistically, we submitted AUC values to a repeated-measures analysis of variance (ANOVA) using factors of typicality and race. The main effect of typicality was significant, $F(1, 25) = 22.87, p < .0001$. Trajectories for atypical White targets ($M = 0.39, SE = 0.05$) curved more toward the “Black” response relative to those for typical White targets ($M = 0.28, SE = 0.04$), $t(25) = 4.34, p < .001$, and trajectories for atypical Black targets ($M = 0.43, SE = 0.06$) curved more toward the “White” response relative to those for typical Black targets ($M = 0.33, SE = 0.04$), $t(25) = 2.74, p = .01$. Neither the main effect of race [$F(1, 25) = 0.633, p = .43$] nor the interaction [$F(1, 25) = 0.02, p = .89$] reached significance. This is evidence that, on the way to arriving at categorizations of atypical targets, both

race categories (White and Black) were simultaneously and partially-active in continuous competition across construal.

Distributional analysis

It is possible that these continuous-attraction effects reflect the averaging together of some trials involving movement straight to the correct category with other trials involving movement initially directed straight at the incorrect category, followed by a sudden reanalysis and corrective movement redirecting the trajectory straight to the correct category. If true, the continuous-attraction effects would be the product of several discrete-like errors biasing the results. We can detect this spurious pattern by inspecting the distribution of trial-by-trial AUC values for bimodality (see Freeman et al., 2008, Study 3, for validation).

The distribution of AUC values for atypical White targets ($b = .444$) and for typical White targets ($b = .378$) were within the $b < .555$ bimodality-free zone (SAS Institute, 1989). To eliminate the possibility that the distribution for atypical White targets was hosting latent bimodal features, the Kolmogorov–Smirnov test verified that the shapes of the distribution for typical White targets and for atypical White targets, once standardized, were statistically indistinguishable ($D = 0.06$, $p = .86$). Similarly, neither the distribution for typical or atypical Black targets showed evidence of bimodality: atypical Black ($b = .476$), and typical Black ($b = .372$), and the Kolmogorov–Smirnov test confirmed that their shapes were statistically indistinguishable ($D = 0.08$, $p = .38$). These analyses confirm that the continuous-attraction effects were not spuriously produced by a combination of discrete-like movements.

Time-course analysis

To better characterize the attraction effects, we calculated, at each time-step, the Euclidean proximity of the mouse position to the opposite-race category. At any given time-step, greater proximity to the opposite-race category in the atypical condition would indicate that category's partial and simultaneous activation as categorization unfolded over time. Separately for White and Black targets, we computed difference scores at each time-step by subtracting the proximity of the typical condition from that of

the atypical condition. The proximity differences are plotted in Fig. 3, indexing across time the degree to which the hand traveled closer to the opposite-race category. A casual inspection of this figure indicates that while the attraction effects for both atypical White and Black targets were manifest continuously across the course of categorization, atypical White targets elicited an attraction effect more consistent throughout the time-course whereas atypical Black targets elicited an effect that was relatively small early on, but then rapidly grew in the later portion of the categorization process.

To more rigorously assess these two patterns of temporal dynamics, we computed four time bins for proximity distances (time-steps: 1–25, 26–50, 51–75, 76–101) and submitted these to a 2 (typicality) \times 2 (race) \times 4 (time bin) repeated-measures ANOVA. Only effects involving the typicality factor are reported. Beyond the main effect of typicality [$F(1, 25) = 36.62$, $p < .0001$], this analysis revealed a marginally-significant three-way interaction [$F(3, 75) = 2.50$, $p = .07$] and a significant typicality \times time bin interaction [$F(3, 75) = 18.06$, $p < .0001$]. These interaction effects arose because, for White targets, trajectories in the atypical condition showed strong attraction to the “Black” response (relative to those in the typical condition) consistently throughout time bins 1 [$t(25) = 2.71$, $p = .01$], 2 [$t(25) = 4.44$, $p < .001$], and 3 [$t(25) = 4.56$, $p = .0001$], whereas, for Black targets, trajectories in the atypical condition showed relatively weak attraction at the beginning, with non-significant attraction at time bin 1 and marginally significant attraction at time bin 2 [$t(25) = 1.83$, $p = .08$], but then a substantial rise in attraction later in time bin 3 [$t(25) = 4.36$, $p < .001$]. These different patterns of temporal dynamics are best illustrated in Fig. 3. Thus, although the atypical White and Black faces induced equivalent amounts of continuous attraction toward the opposite-race category [as there was no typicality \times race interaction: $F(1, 25) = 0.80$, $p = .38$], these effects were temporally distributed in different ways. This indicates that the partial and simultaneous activation of the opposite-race category during categorization of atypical White versus atypical Black faces fluctuated across the course of construal in divergent ways.

Discussion

When categorizing atypical White and Black faces, motor trajectories exhibited a continuous spatial attraction toward the opposite-race category across construal. This is evidence that atypical faces triggered simultaneously and partially-active race-category representations that dynamically competed across the course of categorization. We also found that the processing of White-specifying and Black-specifying cues had different temporal signatures during this competition process. In Study 2, we again record motor trajectories to investigate the temporal dynamics of race perception. This time, however, participants are confronted with faces that are real (rather than computer-generated) and that vary along a continuum of race ambiguity.

Study 2

As in Study 1, participants engaged in a mouse-tracking task in which they were asked to decide whether a face was White or Black. Rather than using computer-generated stimuli, we used real faces that varied along a continuum of race ambiguity. We predict that as ambiguity increases, motor trajectories should show an increasingly stronger attraction to whichever race category is not ultimately selected, indicating competition between alternate race categories settling over time onto a single categorical outcome.

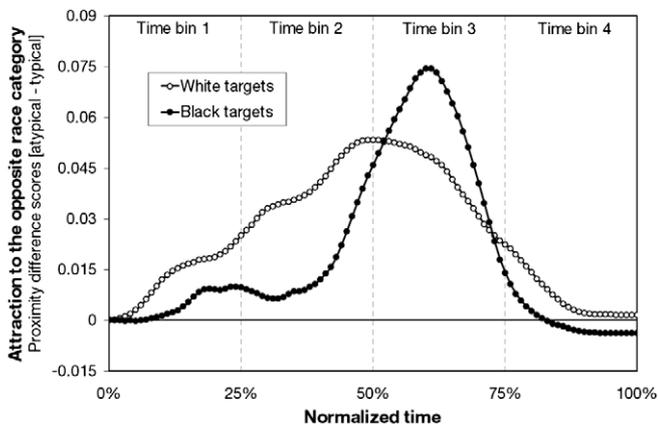


Fig. 3. Separately for the White and Black faces of Study 1, difference scores between the atypical and typical conditions (atypical–typical) in proportional Euclidean proximity ($1 - \text{distance}/\text{max}(\text{distance})$) to the opposite-race category are plotted as a function of normalized time. This indexes across the time the degree to which the hand traveled closer to the opposite-race category for atypical targets relative to typical targets. The atypical White targets induced a relatively consistent continuous-attraction effect, with gradual increase and decrease of partial activation. The atypical Black targets, however, induced an effect with weak attraction at the beginning, which then rapidly rose in the later portion of the trial (and settled). These two different patterns of temporal dynamics were statistically distinguishable.

Method

Participants

Thirty-two undergraduates participated for partial course credit or \$10 (self-identified race/ethnicity: 23 White, 6 Asian, 1 Middle Eastern, 2 declined to report).

Stimuli

We obtained photos (40 male and 40 female images) of self-identifying White, Black, and mixed-race (half Black, half White) individuals who were participating in a separate study on face memory. These individuals varied widely on how racially typical or ambiguous they appeared. These faces were pre-tested ($N = 16$) on racial appearance using a Likert scale (“Does this person look African American or Caucasian?”), ranging from 1 – “Very African American” to 8 – “Very Caucasian.” These ratings were subtracted by a constant of 4.5, converted into absolute values, and re-scaled to vary between -0.5 (typicality) and 0.5 (ambiguity).

Procedure

We used analogous procedures to Study 1. Beyond the AUC measure used in Study 1, we also computed a measure of complexity. If the competition between race categories gets more severe as race ambiguity increases, the increased simultaneous pull on participants’ hand movements from both categories should manifest as less smooth and more complex, unpredictably fluctuating trajectories (as the hand was simultaneously attracted to both categories on opposite sides of the screen). To capture fluctuations in hand movements vacillating between the White and Black response alternatives, representing motor output complexity, we calculated “x-flips:” the amount of reversals of direction along the x-axis (the axis of decision), as has been used in previous research (Dale, Roche, Snyder, & McCall, 2008).

Results

Trajectories were preprocessed using the same procedures as in Study 1. We remapped trajectories (inverted them along the x-axis) so that whichever race category was ultimately selected was located at the top-right. Regardless of whether participants perceived a face to be White or Black, we were interested in whether the amount of racial ambiguity affected mouse trajectories en route to indicating that perception. To determine this, we regressed AUC values and x-flips onto pre-test ambiguity scores (separately). To conduct these regression analyses using trial-by-trial data while appropriately controlling for the intracorrelations in a repeated-measures design, we adopted a generalized estimating equation approach (Zeger & Liang, 1986). We report unstandardized regression coefficients.

As race ambiguity increased (i.e., as a face depicted the unselected race category more strongly), mouse trajectories’ attraction toward the opposite-race category linearly increased, $B = 0.440$, $SE = 0.07$, $p < .0001$ (Fig. 4). Targets’ race ambiguity influenced trajectories’ complexity as well, with more ambiguity corresponding to more x-flips, $B = 0.657$, $SE = 0.18$, $p < .001$ (Fig. 4).

Discussion

We found that, as targets became more racially ambiguous, the competition between race categories correspondingly increased. This was evidenced by increases in racial ambiguity leading to increases in trajectories’ attraction toward the unselected race category and trajectories’ vacillating motions between categories. This extends the results of Study 1, showing that category competition sensitively increases and decreases depending on the amount of racial ambiguity challenging the perceptual system.

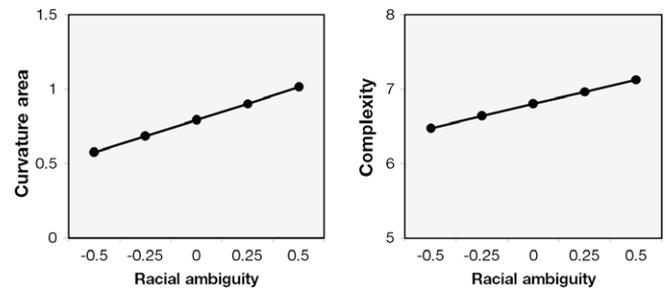


Fig. 4. The attraction to the unselected race category, indexed by AUC, is plotted as a function of faces’ pre-test ambiguity scores, illustrating a positive linear relationship. Motor output complexity, indexed by x-flips, and is also plotted as a function of ambiguity scores, illustrating a positive linear relationship.

General discussion

Across two studies, we provided evidence for continuous dynamics in real-time race perception. In Study 1, atypical White and Black faces triggered simultaneously and partially-active race categories that competed across the course of categorization. This was evidenced by motor trajectories’ continuous attraction toward the opposite-race category across construal. In Study 2, we found that as racial ambiguity gradually increased, the competition between simultaneously active race categories became correspondingly more severe, indicated by increases in trajectories’ attraction toward the opposite-race category and increases in trajectories’ movement complexity.

The present studies resulted in several novel findings that have theoretical implications for the dynamics of person perception more broadly. In Study 1, we found that White-cueing and Black-cueing features on atypical targets induced an equivalent amount of partial and simultaneous activation of their respective race category, but differed in how this activation fluctuated across the course of construal. Whereas partial Black cues led the hand to travel closer to the “Black” response relatively consistently throughout the categorization process, partial White cues did not bear a substantial effect until approximately 40% of categorization had elapsed, at which point a partial activation of the White category rapidly grew and settled (see Fig. 3). These different patterns of temporal dynamics are fitting given the asymmetric nature of White and Black categories, such that Black cues are more likely to capture attention and spontaneously activate category representations than White cues (Smith & Zarate, 1992). These results indicate that, when participants encountered an atypical White face, partial Black cues began biasing the competition early—as Black cues are highly salient—and this competition persisted across the course of categorization until participants finally settled onto a “White” response. However, when encountering an atypical Black target, the majority of Black cues were dominant during the early portion of the competition—as Black cues are highly salient—while the White cues were not well represented. However, after a slight delay now-better-represented partial White cues exerted a strong bias that then yielded to the predominance of accruing perceptual evidence for the Black category. Thus, although prior work has investigated similar asymmetries on the outcomes of social categorization (e.g., Zarate & Smith, 1990), well before these outcomes are even realized, perceptual cues belonging to different sorts of social categories may exert different dynamic patterns of influence over the perceptual-cognitive processing that creates those outcomes.

It may be tempting to inspect the mean trajectories (Figs. 1 and 2) and attempt to pinpoint “when” a race-category decision occurred. For instance, perhaps the moment when the mouse first deviated from the horizontal center ($x = 0$) towards the correct

response is when a decision was made. We would argue, however, that there is no single moment at which a decision occurs; rather, all processing leading up to the mouse-click (including motor execution of the mouse-click itself) is temporally dynamic (see Spivey, 2007). As described earlier, during early moments of face processing a rough sketch of the face rapidly accumulates into neuronal populations, which would afford a quick-and-dirty interpretation of another's race that continuously sharpens across processing (Rolls & Tovee, 1995; for supporting ERP evidence in humans, see Freeman et al., 2009). Thus, early on, mouse movements could already begin heading in the direction of the correct response, but this need not indicate that a decision about a face's race has already been made; it would simply indicate that, during these moments, the competition was predominantly swung toward the correct category. But the competition is likely not over. Although the mouse may start travelling in the correct direction, the other race category may still be simultaneously active. For instance, imagine a moment where the transient interpretation of a face's race is 75% in support of the White category and 25% in support of the Black category. The mouse should already be heading in the direction of a "White" response (as the White category is predominantly activated), thus deviating from $x = 0$, but it should nonetheless still be partially attracted to the "Black" response (as the Black category is still 25% activated). Thus, in our view, there is no instantaneous moment to pinpoint at which one race-category is discretely selected and other categories vanish from working memory. Rather, an ultimate race categorization may simply be the end-result of continuously-fluctuating category representations that gradually settle into a stable, steady state (Freeman et al., 2008; Spivey & Dale, 2004). However, there could be qualities about the way the hand maneuvers a mouse or other response-output factors that preclude this interpretation, and the notion that continuous motor output can be used to faithfully infer continuous perceptual-cognitive processing has not gone unchallenged (van der Wel, Eder, Mitchel, Walsh, & Rosenbaum, 2009).

The present findings also bear implications for downstream person perception. Although the hand's attraction to the opposite-race category could be said to "end" with the mouse-click, this does not likely mark the "end" of that category's partial activation. For instance, using mouse-tracking, we previously found that partial sex-category activation can cascade into the triggering of associated stereotype knowledge (Freeman & Ambady, 2009). More broadly, there are lasting effects of even the subtlest of race-category activations on social judgment, evaluation, and behavior (e.g., Blair, Judd, Sadler, & Jenkins, 2002; Macrae & Bodenhausen, 2000), which can bear serious outcomes such as criminal sentencing (Blair, Judd, & Chapleau, 2004; Johnson, Eberhardt, Davies, & Purdie-Vaughns, 2006). Here we provided evidence for partial "traces" of activation that belong to alternative race categories and can fluctuate across construal. It will be important for future research to investigate how partially-active representations of alternative race categories shape judgment, evaluation, and behavior.

One limitation of the mouse-tracking paradigm was that it constrained participants to making monoracial categorizations. Although recent work suggests that people effortlessly slot racially-ambiguous faces into monoracial categories (Bodenhausen & Peery, 2009; Pauker et al., 2009; Peery & Bodenhausen, 2008), an increasingly heterogeneous racial landscape is leading to the recognition of more multiracial identities at both an individual and institutional level (Jones & Syments Smith, 2001; Lee & Bean, 2004; Pauker & Ambady, 2009; Renn, 2009; Rockquemore, Brusma, & Delgado, 2009). The present research provides a promising look at the future of race categorization in this heterogeneous landscape. Even when perceivers are constrained to making monoracial categorizations, we show that before these race-category decisions are settled into, the story is a lot fuzzier. For the vast majority of

race processing, we find that perceivers entertain many dynamically-changing in-between states amidst traditional race categories—even when targets are slotted into traditional categories if demanded by the task (or society). Thus, the present studies show that social categorization is inherently capable of supporting all sorts of fuzzy, graded mixtures of multiracial interpretations. Before perceivers ultimately fit another's face into a traditional race category, it goes through an ongoing process of fluctuating interpretation that is, in a sense, inherently "mixed-race" (e.g., 60% White, 40% Black). That race categorization flexibly supports these sorts of graded categorical blends—even for fractions of a second—provides promise for the future of social categorization in a more heterogeneous cultural milieu, ripe with people that blur traditional categorical lines. It will be interesting for future research to apply a mouse-tracking paradigm and dynamic framework to understanding the resolution of racially-ambiguous targets into explicitly multiracial, rather than monoracial, categories.

Since the writings of Allport (1954), a thorny issue for social psychology to tackle has been the relationship between race categorization and prejudice. Categorization was long thought to be an inevitable consequence of the perception of others (Allport, 1954), but recent work has sought evidence for the avoidable nature of categorization in the hopes that this could mitigate prejudice (e.g., Blair, 2002; Kurzban, Tooby, & Cosmides, 2001; Macrae & Bodenhausen, 2000). Here we show that, although others are eventually slotted into monoracial categories, the fuzzy overlap with other tentative categories (e.g., White, for a mixed-race face seen as Black) is—although not reflected in the categorization outcome—actually dynamically retained in the process, in those fleeting moments between catching sight of another's face and settling into an eventual category. Knowing that the race categorization process can support these transitory, categorical in-between states, future research might examine whether these could ever manifest in ultimate categorization outcomes, potentially bearing implications for the tendency to prejudge others by oversimplified monoracial categories.

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