

Will a Category Cue Attract You? Motor Output Reveals Dynamic Competition Across Person Construal

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People use social categories to perceive others, extracting category cues to glean membership. Growing evidence for continuous dynamics in real-time cognition suggests, contrary to prevailing social psychological accounts, that person construal may involve dynamic competition between simultaneously active representations. To test this, the authors examined social categorization in real-time by streaming the x , y coordinates of hand movements as participants categorized typical and atypical faces by sex. Though judgments of atypical targets were largely accurate, online motor output exhibited a continuous spatial attraction toward the opposite sex category, indicating dynamic competition between multiple social category alternatives. The authors offer a dynamic continuity account of social categorization and provide converging evidence across categorizations of real male and female faces (containing a typical or an atypical sex-specifying cue) and categorizations of computer-generated male and female faces (with subtly morphed sex-typical or sex-atypical features). In 3 studies, online motor output revealed continuous dynamics underlying person construal, in which multiple simultaneously and partially active category representations gradually cascade into social categorial judgments. Such evidence is challenging for discrete stage-based accounts.

Keywords: social perception, continuity, social cognition, dynamical systems, categorization

In 1972, popular icon, David Bowie, debuted to the world his alter-ego celebrity, Ziggy Stardust, an androgynous alien rock star donned in flaming red hair and extravagant costumes. Not quite male or female, neither Earthling nor extraterrestrial, Bowie attained superstardom in just a few months. Fans and onlookers glorified him, whereas others were repulsed, as the press hailed this indefinable defier of social categorization as the ultimate rock star. As admirers and scholars alike can assure (e.g., Buckley, 1999), it was, at least in part, Bowie's androgyny and betrayal to categorization that rendered him an object of speculation, mystery, and undying fascination. Bowie exemplifies the importance of social categorization. Indeed, whether they be famed or fameless, categorizing others is central in everyday life.

Social psychologists have spent a great deal of time thinking about this categorical processing in social perception. Initial work theorized perceiving others by their social group membership to be an inevitable economizing strategy used to streamline an exhausting amount of social information (Allport, 1954). Recent work, however, has challenged the inevitability of this process (Blair, 2002; Macrae & Bodenhausen, 2000). When and how social

categories come to be automatically activated is an ongoing line of inquiry in social cognition because, as social psychological research has charted quite thoroughly, the mere activation of a social category representation consequentially affects subsequent interaction, judgment, and behavior. Activated category representations shape subsequent encoding and representation of any information relevant to the target (Bodenhausen, 1988). After a social category is activated, its corresponding knowledge structure becomes a lens that molds the judgments perceivers make and impressions they form (Brewer, 1988; Fiske & Neuberg, 1990), and distorts perceivers' memories of a target (Hamilton & Sherman, 1994). Not only does the triggering of a social category bear important cognitive and affective consequences but perceivers' behavior is subject to these influences as well (Bargh, 1997). For instance, activation of the category, Elder, can lead people to walk more slowly (Bargh, Chen, & Burrows, 1996), activation of the category, Black, can cause people to produce more hostility via nonverbal streams (Bargh, Chaiken, Raymond, & Hymes, 1996), and activation of the category, Professor, can boost performance on general knowledge tests (Dijksterhuis & Van Knippenberg, 1998). Unquestionably, social category activation results in consequential cognitive, affective, and behavioral outcomes.

Investigations into the perceptual determinants that lead to social category activation are thus quite crucial, acknowledging the compelling consequences that follow this activation. By combining the social cognitive framework of person perception with insights from face processing models, recent work has examined the perceptual construal that determines both overt person categorization and category activation itself. This body of research has tended to focus on examining how low-level processing of stimulus features maps onto higher level stages of the person processing pipeline. For example, one series of studies showed that

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perceivers can more rapidly and efficiently extract category-cueing information (e.g., the target face is male) as compared with identity-triggering information (e.g., the target face is Jonny), and that the extraction of category cues is uniquely impervious to stimulus manipulation and degradation (Cloutier, Mason, & Macrae, 2005). The special ease with which perceivers can decode category cues has thus been interpreted as an important determinant of the predominance of categorical thinking at all later stages of person processing (Cloutier et al., 2005).

Important downstream consequences of perceiving category cues are reaffirmed by findings demonstrating that such cues can function orthogonal to category membership itself in the automatic evaluation (Livingston & Brewer, 2002) and stereotypic attribution (Blair, Judd, Sadler, & Jenkins, 2002) of social targets. Moreover, category-relevant features (e.g., hair, which is a reliable cue indicative of sex and readily utilized in sex categorizations; Brown & Perrett, 1993; Goshen-Gottstein & Ganel, 2000) can automatically trigger category activation itself (Macrae & Martin, 2007). Thus, the extraction of a mere perceptual cue is sufficient to activate a social category representation *per se*. This work has thus provided an important start in opening up the process of social categorization, showing how perceptual cues and their bottom-up operations ultimately lead to the triggering of a social category.

Recently, this body of work has moved beyond investigations into the perceptual conditions that determine whether a social category will simply be activated or not activated. Some studies have begun to examine how features can affect the *strength* of category representations. Using racial morphing, Locke, Macrae, and Eaton (2005) showed that exemplar typicality (i.e., the goodness-of-fit between an exemplar and the category representation stored in long-term memory) can modulate the strength with which perceivers activate these social category representations. Thus, for instance, the degree to which a target possessed more Asian relative to White features led to linear differences in the extent to which Asian was activated. A handful of similar findings has recently been reported in the social psychological literature elsewhere (Livingston & Brewer, 2002; Macrae, Mitchell, & Pendry, 2002; Maddox & Gray, 2002). Indeed, as Locke et al. (2005, p. 418) have noted, such findings raise problems for the dominant “all or nothing” account of social categorical thinking in which a category is limited to two dichotomous states of either on or off, active or inactive. The authors argued that this prevailing binary account falls short of successfully capturing the flexibility and sensitivity of person categorization that has been demonstrated by such studies of exemplar typicality.

Both this prevailing binary account and more flexible graded account of social categorization are founded on the premise that a representation of a social category purely instantiates in and out of working memory to discretely arrive at a categorical judgment, albeit perhaps with variable strengths. This supposition highlights a kinship with discrete representational accounts of cognition (e.g., Dietrich & Markman, 2003; Fodor, 1983; Pylyshyn, 1984) in which discrete nonoverlapping symbolic representations are activated, one at a time, in pure “state” form, congruent with the classical notion of a digital-computational *physical symbol system* (Newell, 1980; Pylyshyn, 1984). In the simplest of cases, according to these accounts, a discrete social category representation is theorized to statically enter working memory (e.g., catching sight of a man triggers a Male category representation). In less simple

cases (e.g., catching sight of a long-haired, feminine-looking man), such accounts propose a rapid stage-based flip-flop, in which initially an incorrect category, Female, is automatically activated, then to be corrected by some discontinuous reanalysis, eventuating in the correct category, Male, being activated (e.g., Macrae & Martin, 2007).

Such discrete stage-based accounts of categorical processing pivot around the assumption that the neural systems underlying cognition compute static and distinct representations and must wait until these representations are instantiated before sending information down to the next discrete stage of the processing pipeline (Dietrich & Markman, 2003; Fodor, 1983; Pylyshyn, 1984). These discrete stage-based accounts continue to be at the heart of social psychological theories of social categorization and person construal (see Bodenhausen, Macrae, & Sherman, 1999; Brewer, 1988; Brewer & Feinstein, 1999; Chaiken & Trope, 1999; Fiske & Neuberg, 1990; Macrae & Martin, 2007; Read & Miller, 1998; Smith, 1996) and, as others have commented, have grounded and guided the disciplines of social and cognitive psychology more broadly (Smith, 1996; Spivey, 2007; Spivey & Dale, 2004). As valuable as these theoretical understandings have been, a growing body of research has raised problems for such discrete stage-based accounts, instead pointing to the notion that the neural systems underlying cognition are likely to *continuously* cascade *partial* products of information processing down a dynamic and interactive processing pipeline (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Miller, 1982; Rumelhart, Hinton, & McClelland, 1986; Spivey, 2007; Spivey & Dale, 2004, 2006). Such a dynamic continuity account, integral to an emergent *continuity of mind* framework (Spivey, 2007; Spivey & Dale, 2004) rooted in the dynamical systems approach to cognitive science (Port & van Gelder, 1995) and attractor neural network models, argues that perceptual-cognitive processing exhibits continuous—and not discrete—changes in the salience of multiple simultaneously activated representations. Indeed, growing evidence for the continuous dynamics in real-time cognition (Dale, Kehoe, & Spivey, 2007; Farmer, Anderson, & Spivey, 2007; Spivey, 2007; Spivey & Dale, 2004, 2006; Spivey, Grosjean, & Knoblich, 2005; Spivey, Richardson, & Dale, in press) suggests that, across the course of a given cognitive process, as the cognitive system dynamically approximates one of competing mental states (e.g., Male or Female), it entertains a graded mixture of partially consistent representations that continuously flow into—rather than discretely arrive at—a stable response (e.g., “I see a male!”).

This dynamic continuity account would thus envision person categorization as an interactive process in which multiple social category alternatives (e.g., Male or Female) are simultaneously and partially active, continuously competing for activation while perceptual evidence for alternatives is gradually mounted. Reminiscent of information accumulation and feature sampling models (Lamberts, 2000, 2002), various aspects of a stimulus (e.g., a face) may be accessed and reaccessed in parallel, triggering multiple and concurrently active mental representations that are probabilistic rather than pure (Dale et al., 2007; Spivey, 2007; Spivey & Dale, 2004). This dynamic continuity account thus suggests that during those fuzzy and indeterminate fractions of a second between, for instance, catching a glimpse of another’s face and recognizing that person’s sex, neuronal populations would be dynamically fluctuating between patterns of activity that are always partially and

simultaneously consistent with multiple social categorical interpretations (e.g., Male and Female).

Various behavioral techniques have been used to provide indirect evidence for this dynamic flux of partial and simultaneous activation of multiple representations, which continuously cascade into later processing stages and gradually settle on eventual categorical outcomes (see Dale et al., 2007; Spivey & Dale, 2004). Most of these techniques involve continuous real-time measures, such as online hand movements (e.g., Dale et al., 2007; Spivey & Dale, 2004, 2006; Spivey et al., in press) and eye movements (e.g., McMurray, Tannenhaus, Aslin, & Spivey, 2003; Spivey, Tannenhaus, Eberhard, & Sedivy, 2002). Using continuous movements to study cognitive processing is valid considering that motor execution is contiguous with cognitive processes (Abrams & Balota, 1991; Gold & Shadlen, 2000, 2001; Port & van Gelder, 1995; Shin & Rosenbaum, 2002; Spivey, 2007; Spivey et al., in press), and indeed attempts to reveal the graded nature of cognitive processes from continuous movement have a precedent of over 2 decades (Abrams & Balota, 1991; Coles et al., 1985; Spivey et al., in press). Using online motor movement as processing unfolds over time, researchers have mounted evidence for the continuous and dynamical nature of several cognitive processes: semantic categorization (Dale et al., 2007), spoken language processing (Spivey et al., 2005), syntactic ambiguity resolution (Farmer, Anderson, & Spivey, 2007), and others that are more extensively reviewed elsewhere (Spivey, 2007; Spivey & Dale, 2004; Spivey et al., in press).

In one study, for example, participants categorized animal pictures (e.g., cat) presented at the bottom of a computer screen by mouse-clicking one of two categories (e.g., "Mammal" or "Fish") in the upper corners of the screen (Dale et al., 2007). Critical trials involved atypical animals (e.g., whale) in which the opposite competitor category (e.g., Fish) had considerable featural overlap with the target. Though participants reliably clicked the appropriate category (e.g., Mammal), an analysis of the computer mouse trajectories revealed that participants' motor behavior during atypical trials was continuously more attracted toward the competitor category (on the incorrect side of the computer screen) than during typical trials. This graded and continuous attraction in hand movements toward the opposite category during categorization of atypical exemplars (e.g., whale) can be considered evidence that partial activations of the competitor category (e.g., Fish), caused by the dynamic sampling of perceptual features related to this category (i.e., the visual resemblance between a whale and fish), were simultaneously and partially represented across the course of categorization. Though categorizations were reliably correct, graded online motor responses showed a dynamic spatial attraction induced by continuous—and not discrete—competition between category alternatives battling for online representation.

The continuous, dynamical nature of category competition explored with animal exemplars above highlights the simultaneous and persistent influence of misleading category-cueing features (e.g., overlapping perceptual cues of whales activating Fish), whose resulting partial activations hold a continuous presence across the course of semantic categorization. This contradicts the notion held by stage-based accounts, in which misleading category cues immediately and compulsorily "fool" individuals by first leading them astray, discretely instantiating an incorrect representation (e.g., Fish), which is followed by its discontinuous replace-

ment with the correct representation (e.g., Mammal). Dale et al.'s (2007) findings of continuous competition, however, imply that misleading category cues may result in partial and simultaneous activations that do not terminate discretely with some correcting or more informed category activation, as would be suggested by stage-based accounts. Instead, according to a dynamic continuity account, it is possible that perceptual cues associated with alternative categorical possibilities can induce graded representations that continuously compete; and this dynamic competition can continuously flow into veridical categorical judgments.

The possibility that dynamic competition may underlie the social categorization process, however, has yet to be examined. The mere consideration itself that a social category may be represented by probabilistic partial activations that are dynamic and graded has remained largely impossible in social psychological research. We investigate this consideration here. Although the dynamic and graded qualities of semantic categorization have been established by recent work (Dale et al., 2007), these may or may not hold true for social categorization. Categorizing people unquestionably recruits distinct cognitive operations than other types of categorization. Most notably of course is that category cues must be decoded from the complicated stimulus of a face, and face processing is indeed at the service of unique cognitive and corresponding neural computation (Haxby, Hoffman, & Gobbini, 2002; Kanwisher, 2000). Also notable is that categorizing along dimensions of social categories, although indeed uniquely efficient (Macrae & Bodenhausen, 2000), requires the nuanced extraction of a more complex pattern of features than along dimensions of basic object categories.

In the present work, we make use of atypical exemplars (e.g., long-haired men, masculinized women) in tandem with a continuous source of cognitive output (hand movements) to explore whether the social categorization process may proceed in a manner consistent with the dynamic continuity account we have presented here. By opening up a continuous stream of output that speaks to the *process* rather than *product* of social categorization, we can index across time the multiple category activations that lead to ultimate categorical judgments. Such a continuous response measure enables a first interrogation into whether such activations may indeed exhibit dynamic qualities of graded continuity and *granularity* (Miller & Ulrich, 2003)—findings that would be challenging for classical discrete stage-based accounts of social categorization. When atypical cues must be processed, a discrete stage-based account holds that working memory contains one and only one of multiple alternatives, resulting in the initial activation of an incorrect representation, followed by a discontinuous corrective reanalysis, and finally the correct representation (e.g., short-haired woman: Male, and *then* Female). In contrast, the dynamic continuity account we offer predicts simultaneously and partially active category representations in continuous competition (e.g., gradations of Male and Female concurrently online) that progressively flow into a veridical categorical judgment. Whereas these two accounts would not diverge markedly in their expectations using discrete outcome-based measures (e.g., latency of response or categorization accuracy), these two accounts would indeed anticipate quite different results using a continuous nonballistic measure sampling cognitive processing approximately 70 times per second. Here we exploit such a measure to adjudicate between these two accounts for the process of social categorization.

If we were to place each category alternative (e.g., Male vs. Female) at the top-left and top-right corners of the computer screen and ask participants to categorize typical targets (e.g., short-haired men) and atypical targets (e.g., long-haired men) by moving the mouse from the bottom center of the screen to one of the alternatives at the top corners, these accounts would make predictions as follows. If only one representation or the other is switched on in working memory at any given time, as predicted by discrete stage-based accounts, motor output should move in only one of two ways: either discretely toward the incorrect competitor or discretely toward the correct competitor. Two possibilities of motor responses for atypical targets are thus consistent with these accounts: (a) If all trials are sufficient to “fool” participants, trajectories for all trials should initially be directed toward the incorrect competitor and then sharply redirected toward the correct competitor, or (b) if only some trials are sufficient to “fool” participants, “fooled” trajectories should initially head toward the incorrect competitor and be sharply redirected midflight, whereas correct trajectories should travel directly toward the correct competitor. Thus, motor responses for atypical trials should either be (a) distributed unimodally with all trials showing extreme attraction toward the opposite competitor, or (b) distributed bimodally with one population of “fooled” trajectories showing extreme attraction and another population of correct trajectories showing no attraction. However, if both representations (e.g., Male and Female) simultaneously and partially weigh in on participants’ construals, as predicted by a dynamic continuity account, motor responses for atypical trials should show a gradation of continuous attraction toward the opposite competitor. Such responses should thus exhibit moderate attraction that is distributed unimodally, with some trajectories that are more attracted, some that are intermediately attracted, and some that are less attracted. This graded motor output would thereby reveal a continuous attraction toward the opposite competitor (and not discontinuous shifts), reflecting multiple, simultaneous and partially active representations in dynamic competition.

Here we test whether the process of social categorization may be dynamical and continuous rather than static and discrete, placing

into question classical notions regarding the format itself of a social category representation in working memory. We examine this by focusing on the social categorization of sex, the category that has probably received the most thorough attention in the social psychological literature. Categorizing others by sex occurs effortlessly (Macrae & Martin, 2007; Martin & Macrae, 2007; Stangor, Lynch, Duan, & Glass, 1992) and carries weighty consequences (Macrae & Bodenhausen, 2000). Although categorizing along other dimensions (e.g., race and age) has recently been shown to be avoidable under certain conditions (Kurzban, Tooby, & Cosmides, 2001; Quinn & Macrae, 2005), the conditional nature of sex categorization has yet to be established, highlighting a central and persistent role that these categorizations play in our social world.

To explore the continuous dynamics underlying sex categorization, we employ a two-prong strategy. First, in Study 1, we track online motor output across the categorization of real male and female faces that are either typical or atypical, manipulated by hair length (see Figure 1A), a cue that reliably relates to sex and can activate sex category representations per se (i.e., long hair activates Female and short hair activates Male; Macrae & Martin, 2007). These real faces afford breadth and generalizability. To permit greater precision and control, however, in Study 2, we use computer-generated male and female face stimuli whose sex-typicality is manipulated by morphing internal facial information along sex, as based on actual anthropometric parameters of the human population (see Figure 1B). As hair is a peripheral cue relative to the internal face, using computer-generated faces allows us to additionally test the dynamic qualities of sex categorization when very subtle—but highly diagnostic—sexually dimorphic internal information of the face may trigger partially active category representations that simultaneously compete across the course of construal. Lastly, in Study 3, we provide an empirical simulation revealing what online motor output across a discrete stage-based process would look like. We then demonstrate a sufficient methodological and statistical sensitivity to identify these motor responses as consistent with discrete stage-based accounts. Demonstrating that these simulated motor responses, consistent with alternative accounts, are incompatible with the results of Studies 1

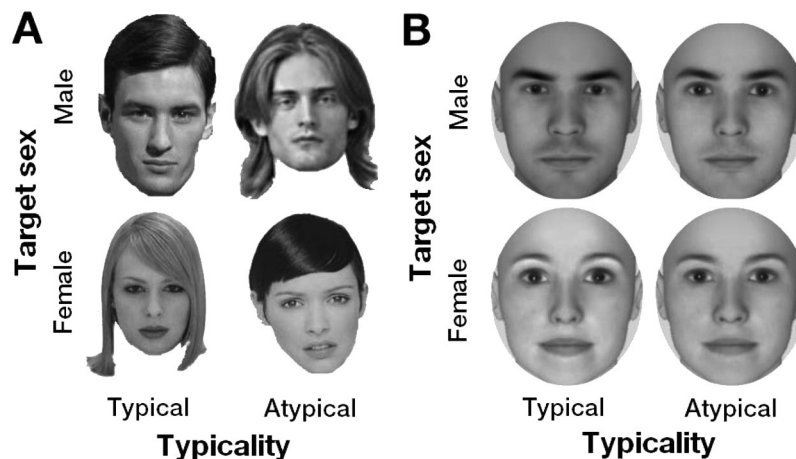


Figure 1. (A) Sample stimuli used in Study 1, in which typicality was manipulated by hair length using real representative faces. (B) Sample stimuli used in Study 2, in which typicality was manipulated by morphing sexually dimorphic internal facial information using computer-generated faces.

and 2 strengthens our evidence for the continuous dynamics underlying social categorization. It also, more broadly, provides a useful paradigm validation of the mouse-tracking technique for distinguishing discrete versus dynamical accounts at large.

Across three studies, we provide converging evidence in support of a dynamic continuity account of social categorization. Tracking the person construal process in real-time, here we test whether atypical category cues may trigger simultaneous and partial activations of social categories that compete continuously across the course of categorization.

Study 1

Here we tracked computer mouse movements as participants categorized real faces by sex. Stimuli included targets with a sex-specifying perceptual cue, hair, that was either typical for their sex (long hair for women and short hair for men) or atypical (short hair for women and long hair for men). In each trial, participants categorized targets by mouse-clicking either the top-left or top-right corners of the computer screen. Participants were presented with a face image at the bottom center of the screen and asked to use the mouse to click either the “Male” or “Female” label in either top corners of the screen.

Presuming that atypical hair cues are sufficient to activate associated sex categories, as shown previously (Macrae & Martin, 2007), a discrete stage-based account predicts motor responses for atypical targets to exhibit either (a) a unimodal population comprised of all extremely attracted trajectories, or (b) a bimodal population comprised of some extremely attracted trajectories and other trajectories showing virtually no attraction. A dynamic continuity account, however, predicts a unimodal population comprised of trajectories showing graded and moderate attraction toward the competitor, continuously across the course of construal. Here we use a continuous source of online cognitive output to adjudicate between a discrete stage-based account and a dynamic continuity account of social categorization.

Method

Participants. Twenty-three undergraduate students participated in a 2 (Target Sex: male and female) \times 2 (Typicality: typical or atypical) within-subject, repeated measures design in exchange for partial course credit or \$10.

Stimuli. Stimuli consisted of 10 photos of faces for each of the within-subject conditions: (a) long-haired women (typical), (b) short-haired women (atypical), (c) short-haired men (typical), and (d) long-haired men (atypical), obtained from public domain Internet websites. Only faces that were directly oriented and free of adornments (e.g., jewelry, moustache, or beard) were selected for use. Images were removed from their original context and placed onto a white background. Hair was retained in the cropping, whereas all other extra-facial information (e.g., neck or body) was removed. Images were gray-scaled, standardized by brightness and contrast, and resized to 200 \times 200 pixels. To manipulate hair length, we ensured that long hair was sufficiently long enough to appear typical (for female targets) or atypical (for male targets) while not being so long as to bias the proportions of the stimulus; this resulted in long hair ranging between approximately chin-length and shoulder-length (see Figure 1A).

Procedure. To record computer mouse movements, we developed customized in-house software using Visual Basic 6 programming language (Microsoft, Redmond, WA). This allowed us to sample the mouse location at an average of 70.43 Hz across studies. Participants were told that they would be presented with target faces at the bottom of the screen and asked to categorize these by mouse-clicking on the appropriate label at the top corners of the screen. Before the presentation of each face, participants had to click on a “Start” button located at the center bottom of the screen. After clicking this button to initiate the trial, the mouse was automatically relocated to the center point of the bottom edge of the screen, that is, with x -, y -coordinates of “0, 0.” Targets were presented in a randomized order and were categorized as male or female by mouse-clicking either the “Male” or the “Female” label, located in the top-left and top-right corners of the screen (randomized across participants). Participants were given six practice trials before experimental trials took place. Judgment, latency of response, initiation time (the moment when the mouse was first moved), and movement trajectories (i.e., x -, y -coordinates of the mouse position) were recorded.

Results

Data preparation and screening. To permit averaging from multiple trials to directly compare conditions, we time- and space-normalized movement trajectory data. We fit trajectories to 101 time steps using linear interpolation, and we rescaled them to a coordinate space with x -, y -coordinates of “-1, 1.5” at the top left pixel and “1, 0” at the bottom right, leaving “0, 0” at the start location of the mouse. Leftward responses thus started at “0, 0” and were directed toward “-1, 1.5,” whereas rightward responses were directed toward “1, 1.5.” Because response label position was assigned randomly to the two corners, trajectories for typical and atypical male targets were remapped leftward, whereas trajectories for typical and atypical female targets were remapped rightward before the normalization procedures.

Before submitting movement trajectories for analysis, every trajectory was individually examined for aberrant movements (i.e., erratic output producing noninterpretable looping cycling leftward and rightward), which resulted in a discard of 12 trials (typical male, 4; atypical male, 0; typical female, 3; atypical female, 5). Trials whose response times were extremely long (4,000 ms or greater) were additionally excluded, resulting in a discard of two trials (typical male, 0; atypical male, 0; typical female, 0; atypical female, 2). Participants made 13 categorization errors, and these trials were excluded from subsequent analyses (typical male, 1; atypical male, 4; typical female, 0; atypical female, 8). Overall, 2.9% of the data was discarded.

To assess trajectory curvature (i.e., the degree to which the mouse was spatially attracted toward the opposite category label on the opposite side of the computer screen), we computed the area between each observed trajectory and a corresponding ideal response trajectory (a straight line between its start and endpoint). Any curvature heading away from the opposite category label and away from the ideal response trajectory was computed as negative area. We also computed the maximum deviation away from this ideal response trajectory (i.e., subtraction between ideal and observed x -coordinates) for each trial. Maximum deviation was calculated as the largest positive deviation out of all 101 time steps.

Initial analyses. Participants' gender had a negligible effect on task performance in the present study and in Studies 2 and 3, and thus is discussed no further.

First, we assessed whether target sex or typicality had an effect on response latencies using a 2 (Target sex) \times 2 (Typicality) repeated measures analysis of variance (ANOVA). A main effect for sex did not reach significance, $F(1, 22) = 1.41$, $MSE = 14,640$, $p = .25$, $\eta_p^2 = .06$, nor did the interaction, $F(1, 22) = 1.32$, $MSE = 12,656$, $p = .26$, $\eta_p^2 = .57$. A main effect for typicality, however, was significant, $F(1, 22) = 25.10$, $MSE = 6,250$, $p < .0001$, $\eta_p^2 = .53$, such that typical targets were categorized more quickly relative to atypical targets. Specifically, this facilitation was significant for female targets, $t(22) = 4.37$, $r = .68$, $p < .001$, such that females were categorized more quickly when typical ($M = 1,294$ ms, $SE = 76$ ms) than atypical ($M = 1,404$ ms, $SE = 84$ ms), but was not significant for male targets, $t(22) = 1.75$, $r = .35$, $p = .10$, though there was a trend of males being categorized more quickly when typical ($M = 1,292$ ms, $SE = 77$ ms) than atypical ($M = 1,347$ ms, $SE = 70$ ms).

We also examined whether target sex or typicality had an effect on initiation times using a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 22) = 0.08$, $MSE = 5,392$, $p = .78$, $\eta_p^2 < .01$, nor did the interaction, $F(1, 22) = 0.20$, $MSE = 4,922$, $p = .66$, $\eta_p^2 < .01$. A main effect for typicality, however, was significant, $F(1, 22) = 19.73$, $MSE = 4,497$, $p < .001$, $\eta_p^2 = .47$, such that atypical targets experienced a slight delay in being initiated relative to typical targets. Specifically, trajectories for male targets were initiated more quickly when typical ($M = 603$ ms, $SE = 39$ ms) than atypical ($M = 672$ ms, $SE = 44$ ms), $t(22) = 3.13$, $r = .56$, $p < .01$, and trajectories for female targets were initiated more quickly

when typical ($M = 614$ ms, $SE = 46$ ms) than atypical ($M = 669$ ms, $SE = 47$ ms), $t(22) = 3.06$, $r = .55$, $p < .01$.

Spatial attraction. Mean trajectories were computed for typical and atypical male targets and for typical and atypical female targets. Plotted in Figure 2, trajectories for atypical targets reveal a distinct curvature toward the competitor category on the opposite side of the screen. Trajectories for atypical (long-haired) male targets show a continuous attraction toward "Female" relative to trajectories for typical (short-haired) male targets, and trajectories for atypical (short-haired) female targets show a continuous attraction toward "Male" relative to trajectories for typical (long-haired) female targets. We submitted these trajectory data to several analyses.

First, we assessed whether target sex or typicality had an effect on our two computed measures of trajectory curvature: curvature area and maximum deviation. We submitted curvature areas to a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 22) = 0.12$, $MSE = 0.02$, $p = .72$, $\eta_p^2 < .01$, nor did the interaction, $F(1, 22) < 0.01$, $MSE = 0.02$, $p = .94$, $\eta_p^2 < .01$. More critically, however, a main effect for typicality was significant, $F(1, 22) = 8.56$, $MSE = 0.03$, $p < .01$, $\eta_p^2 = .28$, such that trajectories for atypical targets were more attracted toward the competitor category on the opposite side of the computer screen relative to trajectories for typical targets. Specifically, trajectories for male targets were more attracted toward "Female" when targets were atypical (long-haired; $M = 0.67$, $SE = 0.04$) relative to typical (short-haired; $M = 0.56$, $SE = 0.04$), $t(22) = 2.11$, $r = .41$, $p = .05$, and trajectories for female targets were more attracted toward "Male" when targets were atypical (short-haired; $M = 0.66$, $SE = 0.04$) relative to typical (long-haired; $M = 0.55$, $SE = 0.03$), $t(22) = 2.46$, $r = .46$, $p < .05$.

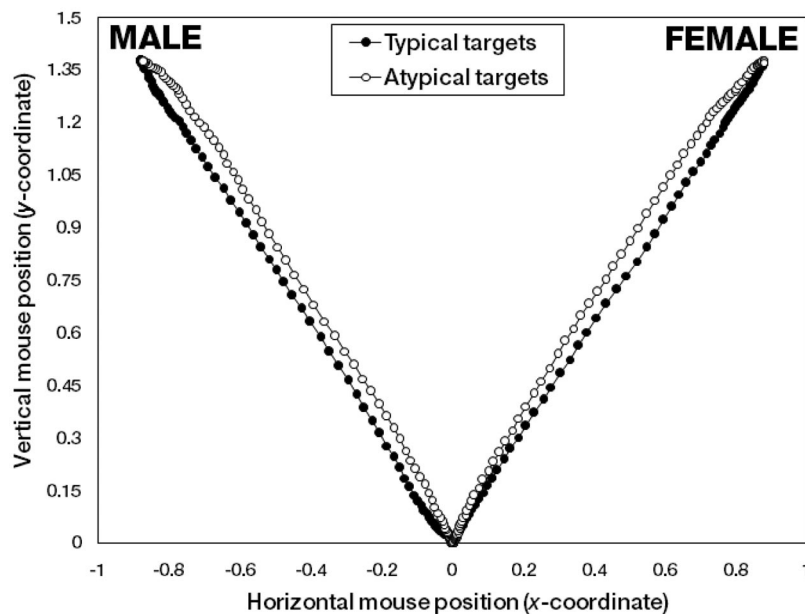


Figure 2. Mean mouse trajectories in Study 1. Trajectories for male targets are shown leftward, and trajectories for female targets are shown rightward. Trajectories for atypical (long-haired) male targets exhibit a statistically reliable continuous attraction toward "Female," and trajectories for atypical (short-haired) female targets exhibit a statistically reliable continuous attraction toward "Male."

Next, we submitted maximum deviations to a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 22) < 0.01$, $MSE = 0.01$, $p = .95$, $\eta_p^2 < .01$, nor did the interaction, $F(1, 22) = 0.35$, $MSE = 0.01$, $p = .56$, $\eta_p^2 = .02$. More critically, however, a main effect for typicality was significant, $F(1, 22) = 21.39$, $MSE = 0.01$, $p < .001$, $\eta_p^2 = .49$, with trajectories for atypical targets deviating more toward their competitor category relative to those for typical targets. Specifically, trajectories for male targets deviated more toward “Female” when targets were atypical (long-haired; $M = 0.19$, $SE = 0.02$) relative to typical (short-haired; $M = 0.11$, $SE = 0.02$), $t(22) = 3.76$, $r = .63$, $p = .001$, and trajectories for female targets deviated more toward “Male” when targets were atypical (short-haired; $M = 0.18$, $SE = 0.02$) relative to typical (long-haired; $M = 0.12$, $SE = 0.01$), $t(22) = 3.35$, $r = .58$, $p < .01$.

We also directly compared trajectories for typical versus atypical targets without collapsing the trajectory of each trial into a single parameter (i.e., curvature area or maximum deviation). To assess whether trajectories for atypical male targets were reliably attracted toward “Female,” we used paired samples t -tests to examine whether the x -coordinate of trajectories for atypical (long-haired) targets significantly diverged toward “Female” relative to trajectories for typical (short-haired) targets at each of the 101 time steps. To assess whether trajectories for atypical female targets were reliably attracted toward “Male,” we used another series of 101 paired samples t -tests to examine whether the x -coordinate of atypical (short-haired) trajectories significantly diverged toward “Male” relative to typical (long-haired) trajectories. Consistent with previous research (Dale et al., 2007), as a conservative test, divergences were considered reliable only when a minimum of eight consecutive time steps were significant at a criterion of $p < .05$. This qualification was determined by a bootstrap analysis of 10,000 simulated experiments, showing that a sequence of eight significant t -tests was sufficient to maintain a false positive detection rate at $p < .01$.

Trajectories for atypical male targets showed reliable attraction toward the competitor category relative to typical male targets from the 27th to the 93rd time steps ($ps < .05$). Thus, relative to typical male targets, the average mouse position when categorizing atypical male targets significantly diverged toward the “Female” label between the 27th and 93rd time steps. Trajectories for atypical female targets showed reliable spatial attraction toward the competitor category relative to typical female targets from the 57th to the 76th time steps ($ps < .05$). Thus, relative to typical female targets, the average mouse position when categorizing atypical female targets significantly diverged toward the “Male” label between the 57th and 76th time steps.

To preserve information about normalized time but avoid the issue of multiple comparisons encountered in the previous analysis of trajectory divergence, we created four time bins based on normalized time steps (1–25, 26–50, 51–75, 76–101) and conducted a 2 (Typicality) \times 4 (Time) repeated measures ANOVA on x -coordinates, separately for trajectories for male targets and trajectories for female targets. The means and standard errors for all possible combinations of the four time bins crossed with typicality for trajectories in the male and female conditions appear in Table 1.

For trajectories in the male condition, this analysis yielded a significant main effect for typicality, $F(1, 22) = 17.90$, $MSE = 0.01$, $p < .001$, $\eta_p^2 = .45$, such that trajectories for male targets

Table 1
Means (and Standard Errors) for the Analyses of Variance of Time-Binned x -Coordinates in Study 1

Time bin	Male		Female	
	Typical	Atypical	Typical	Atypical
1 [1–25]	-.003 (.002)	-.002 (.001)	.003 (.003)	.003 (.002)
2 [26–50]	-.114 (.023)	-.075 (.017)	.093 (.019)	.084 (.019)
3 [51–75]	-.590 (.043)	-.528 (.048)	.588 (.041)	.534 (.048)
4 [76–101]	-.854 (.013)	-.826 (.018)	.851 (.014)	.837 (.020)

were closer toward the “Female” response label when targets were atypical relative to typical. This analysis also revealed a significant main effect for time,¹ $F(3, 66) = 319.46$, $MSE = 0.02$, $p < .0001$, $\eta_p^2 = .94$, and a significant interaction, $F(3, 66) = 4.17$, $MSE = 0.01$, $p < .01$, $\eta_p^2 = .16$. Pairwise comparisons between the typical and atypical conditions at each of the four time bins revealed reliable attraction toward “Female” for atypical male targets at the second time bin, $t(22) = 2.83$, $r = .52$, $p = .01$; third time bin, $t(22) = 3.00$, $r = .54$, $p < .01$; and final time bin, $t(22) = 2.93$, $r = .53$, $p < .01$.

For trajectories in the female condition, the 2 (Typicality) \times 4 (Time) ANOVA on x -coordinates revealed a significant main effect for typicality, $F(1, 22) = 5.43$, $MSE = 0.01$, $p < .05$, $\eta_p^2 = .20$, such that trajectories for female targets were closer toward the “Male” response label when targets were atypical relative to typical. This analysis also revealed a significant main effect for time (see Footnote 1), $F(3, 66) = 360.03$, $MSE = 0.02$, $p < .0001$, $\eta_p^2 = .94$, and a significant interaction, $F(3, 66) = 3.49$, $MSE = 0.01$, $p = .02$, $\eta_p^2 = .14$. Pairwise comparisons between the typical and atypical conditions at each of the four time bins revealed a reliable attraction toward “Male” for atypical female targets at the third time bin, $t(22) = 2.53$, $r = .48$, $p < .05$.

Discrete stage-based versus dynamic continuity accounts. Converging across multiple measures and analyses, the reliable spatial attraction toward the competitor across the categorization of atypical targets suggests that both social category representations (Male and Female) were simultaneously and partially active in continuous competition across construal. Note that this spatial attraction appears continuous and graded, showing moderate curvature toward the opposite category, and does not appear extreme and discrete like an abrupt midflight correction. This spatial attraction is thus consistent with the dynamic continuity account we have described here. As discussed earlier, however, this graded attraction must be distributed unimodally rather than bimodally to be consistent with a dynamic continuity account. Specifically, if on some trials motor output was extremely attracted to the competitor (e.g., sharply corrected midflight) and on other trials motor output

¹ Some readers may be surprised by the observed F value for the main effect for time (first, second, third, fourth) in each of the ANOVAs of time-binned x -coordinates in Studies 1 and 2. The F values for these tests are especially large because as time increased from the first time bin to the final time bin, x -coordinates inevitably had to draw closer to the response label. Thus, at different levels of time, there were substantial differences in x -coordinates with a minimal amount of error, producing a perhaps startling observed F value. This was anticipated.

was virtually not at all attracted—a possibility consistent with discrete stage-based accounts—after averaging, mean motor output could spuriously produce graded curvature similar to that obtained here. To ensure this was not the case, we inspected the distribution of trajectory curvatures to probe for bimodality. As has been noted previously (Farmer, Cargill, Hindy, Dale, & Spivey, 2007), curvature area is an optimal response measure to statistically observe bimodality. We thus submitted curvature areas to several distributional analyses.

First, all movement trajectories corresponding with the atypical male condition (see Figure 3A) and atypical female condition (see Figure 3B), along with their respective mean trajectories, were plotted to provide the opportunity for a casual but comprehensive graphical assessment of the distribution of trajectory responses. Note that although indeed there are several straying trajectories leaping toward the competitor, the vast majority of trajectories appear to be distributed as a single unimodal population in which some trajectories are relatively less attracted, some are intermediately attracted, and some are relatively more attracted toward the competitor.

To more rigorously assess this premise, we converted curvature areas for typical male targets and atypical male targets together into z -scores within a participant, and then we pooled these across participants. Figure 3C depicts the z distribution for atypical male

targets ($n = 226$; $M = .13$; variance = 1.00; kurtosis = $-.52$; skewness = $-.02$), which is similar to the z distribution for typical male targets ($n = 225$; $M = -.14$; variance = 0.87; kurtosis = $-.67$; skewness = $.09$). For both distributions, we computed the bimodality coefficient b (SAS Institute, 1989), which has a standard cutoff value of $b = 0.555$. Values that exceed 0.555 are considered evidence to reject unimodality in favor of bimodality. Neither distribution had any indication of bimodality (atypical male, $b = 0.397$; typical male, $b = 0.425$).

We can also alleviate concerns that the distribution for atypical male targets might host underlying bimodality by obtaining evidence that the shapes of the distribution for typical male targets and distribution for atypical male targets are statistically identical. To this end, we z -scored curvature areas within each participant, separately for typical male and atypical male targets, and pooled across participants. We used the Kolmogorov–Smirnov test to evaluate any reliable departure between the respective shapes of these two z distributions. This analysis confirmed that the distribution for typical male targets and the distribution for atypical male targets were statistically indistinguishable ($D = 0.04$, $p = .99$), eliminating the possibility that the distribution for atypical male targets may be selectively hosting latent bimodal features.

Similarly, Figure 3D depicts the z distribution for atypical female targets ($n = 215$; $M = .13$; variance = 1.02; kurtosis =

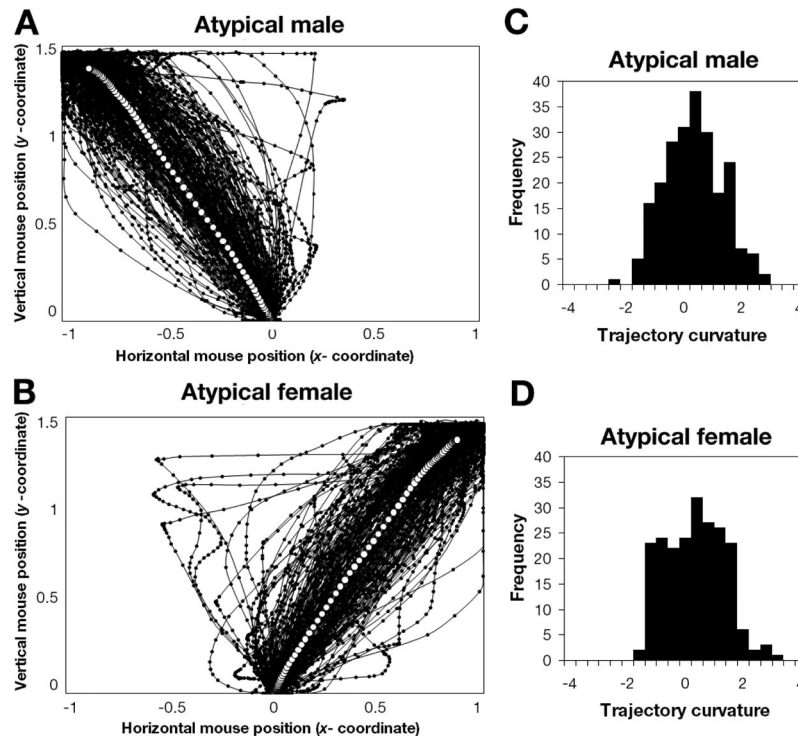


Figure 3. (A) All mouse trajectories in the atypical male condition of Study 1 are overlaid onto one graphical display, along with the mean trajectory, illustrating that the vast majority of trajectories show graded curvature toward the opposite category competitor. (B) All mouse trajectories in the atypical female condition of Study 1 are overlaid onto one graphical display, along with the mean trajectory, illustrating that the vast majority of trajectories show graded curvature toward the opposite category competitor. (C) Distribution of curvature areas in the atypical male condition of Study 1, illustrating unimodality. (D) Distribution of curvature areas in the atypical female condition of Study 1, illustrating unimodality.

-.57; skewness = -.19), which is similar to the z distribution for typical female targets ($n = 227$; $M = -.13$; variance = 0.86; kurtosis = -.88; skewness = .22). Neither distribution had any indication of bimodality (atypical female, $b = 0.420$; typical female, $b = 0.486$), and the Kolmogorov–Smirnov test confirmed that the respective shapes of the distribution for typical female targets and distribution for atypical female targets were statistically indistinguishable ($D = 0.06$, $p = .86$), eliminating the possibility that the distribution for atypical female targets may be selectively hosting latent bimodal features.

Finally, there remains the possibility that, after we normalized and averaged trajectories, potential sharp midflight corrections (consistent with discrete stage-based accounts) occurring along with by-trial variability in initiation times could confound the reported spatial attraction. To rule out this possibility, we examined the reliability of the main effect for typicality on trajectories' curvature areas after including trial-by-trial initiation times as a covariate in a multiple regression analysis. We used generalized estimating equations (GEE) with a general linear model regression analysis rather than an analysis of covariance or typical least-squares regression to sensitively analyze *trial-by-trial* initiation times (rather than average initiation times per participant) while appropriately controlling for the intracorrelations in individual subject data that are typically encountered in repeated measures designs (Zeger & Liang, 1986). Typicality and target sex were coded numerically and centered at 0 ($-0.5 = \text{typical}$, $0.5 = \text{atypical}$; $-0.5 = \text{male}$, $0.5 = \text{female}$). We regressed curvature areas onto typicality, target sex, the interaction between the two, and the covariate of initiation times. Although initiation times did predict curvature areas (unstandardized $B = -0.01$, $SE < 0.01$, $p = .03$), the main effect for typicality was still significant (unstandardized $B = 0.13$, $SE = 0.04$, $p < .001$), thereby eliminating initiation time as a possible confound for the reported spatial attraction effects.

Discussion

The graded and continuous spatial attraction of real-time motor trajectories toward the opposite competitor category across the categorization of atypical targets (long-haired men and short-haired women) suggests that atypical hair cues triggered simultaneously and partially active sex-category representations that dynamically competed across the course of categorization. This continuous competition between sex-category alternatives provides evidence for a dynamic continuity account of the social categorization of sex and is not well accommodated by alternative discrete stage-based accounts. Here we obtained evidence of continuous dynamics across the categorization of real face stimuli. In Study 2, we test whether the dynamic spatial attraction effects found here for atypical targets may extend to sex categorizations of computer-generated faces whose sex-typicality is more precisely manipulated and controlled. This additionally allows us to examine whether very subtle sexually dimorphic internal facial information rather than a sex-specifying peripheral cue, such as hair, may trigger simultaneously and partially active category representations that dynamically compete across the course of sex categorization.

Study 2

We tracked computer mouse movements in real-time as participants categorized computer-generated faces by sex. Morphing along sex allowed us to precisely manipulate sexually dimorphic internal facial information. Whereas in Study 1 every target in the typical condition and atypical condition was a unique target with a unique identity, here we were able to seamlessly generate typical and atypical variants of the very same target. Thus, we were able to manipulate one and only one variable, sex-typicality, and unconfound all other perceptual information. The typical condition included male and female face stimuli whose respective sex was generated at the anthropometric mean. The atypical condition comprised these very same male and female face stimuli, except that their sex was generated at a level systematically closer to the anthropometric mean of the opposite sex.

Differing from Study 1 in which the atypical cues (hair) had been previously shown to activate associated sex categories, it is unclear whether very subtle atypical internal facial information (masculinized cues on women or feminized cues on men) is sufficient to trigger associated sex categories. Discrete stage-based accounts and prevailing theories of social categorization would likely argue that a typical female face, for instance, relative to an atypical (masculinized) female face, would merely trigger a *stronger* representation of Female (e.g., as has been suggested with race; Locke et al., 2005). A dynamic continuity account, however, opens up the possibility that an atypical (masculinized) female face could trigger partial activations not only of Female but *also* of the opposite sex category, Male, that simultaneously and continuously compete across the course of sex categorization.

If atypical internal facial information is *not* sufficient to activate the opposite sex category, discrete stage-based and dynamic continuity accounts both predict that participants' mouse trajectories would show no reliable divergences when categorizing atypical targets versus typical targets. If, however, it is indeed sufficient, a discrete stage-based account predicts motor responses for atypical targets to exhibit either (a) a unimodal population comprised of all extremely attracted trajectories, or (b) a bimodal population comprised of some extremely attracted trajectories and other trajectories showing virtually no attraction. A dynamic continuity account, however, predicts a unimodal population comprised of graded and moderate curvatures toward the competitor across the course of sex categorization.

Method

Participants. Twenty-five undergraduate students participated in a 2 (Target Sex: male and female) \times 2 (Typicality: typical or atypical) within-subject, repeated measures design in exchange for partial course credit or \$10.

Stimuli. To conduct morphing along sex, we used 3-D face-modeling software, FaceGen Modeler 3.1 (Singular Inversions, Vancouver, Canada), enabling the semirandomized generation of face stimuli with a high level of realism. This software allowed for sexually dimorphic internal face information to be manipulated along a continuum of sex, as based on anthropometric parameters of the human population, ranging from *extremely male* to *extremely female*. Ten unique male faces were generated at the anthropometric male mean, and 10 unique female faces were

generated at the anthropometric female mean, together composing the typical condition. The 10 typical male faces were then morphed approximately 25% toward the anthropometric female mean, and the 10 typical female faces were then morphed approximately 25% toward the anthropometric male mean, together composing the atypical condition. Faces were directly oriented and cropped as to preserve only the internal face (see Figure 1B).

Procedure. Participants engaged in the same mouse-tracking paradigm of Study 1. Rather than categorizing real faces, participants categorized the computer-generated stimuli described above.

Results

Data preparation and screening. We prepared and screened trajectory data using the same procedures of Study 1. Because of aberrant movements, 13 trials were discarded (typical male, 3; atypical male, 2; typical female, 8; atypical female, 0). Trials whose response time was extremely long (4,000 ms or greater) were additionally excluded, resulting in a discard of two trials (typical male, 0; atypical male, 0; typical female, 0; atypical female, 2). Participants made 12 categorization errors, and these trials were excluded from subsequent analyses (typical male, 0; atypical male, 3; typical female, 1; atypical female, 8). Overall, 2.8% of the data was discarded.

Initial analyses. First, we assessed whether target sex or typicality had an effect on response latencies using a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 24) = 0.76$, $MSE = 23,297$, $p = .39$, $\eta_p^2 = .03$, nor did the interaction $F(1, 24) = 1.54$, $MSE = 15,304$, $p = .99$, $\eta_p^2 < .001$. More importantly, a main effect for typicality was significant, $F(1, 24) = 14.05$, $MSE = 13,404$, $p = .001$, $\eta_p^2 = .37$, such that typical targets were categorized more

quickly relative to atypical targets. Specifically, male targets were categorized more quickly when typical (masculinized; $M = 1,301$ ms, $SE = 65$ ms) than atypical (feminized; $M = 1,387$ ms, $SE = 66$ ms), $t(24) = 2.73$, $r = .49$, $p = .01$, and female targets were categorized more quickly when typical (feminized; $M = 1,327$ ms, $SE = 62$ ms) than atypical (masculinized; $M = 1,414$ ms, $SE = 82$ ms), $t(24) = 2.42$, $r = .44$, $p = .02$.

We also examined whether target sex or typicality had an effect on initiation times using a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 24) = 1.42$, $MSE = 5,816$, $p = .25$, $\eta_p^2 = .37$, nor did the interaction, $F(1, 24) = 0.90$, $MSE = 5,260$, $p = .35$, $\eta_p^2 = .04$. A main effect for typicality, however, was significant, $F(1, 24) = 9.77$, $MSE = 4,098$, $p < .01$, $\eta_p^2 = .29$, such that atypical targets experienced a slight delay relative to typical targets. Whereas trajectories for female targets were initiated significantly more quickly when typical (feminized; $M = 626$ ms, $SE = 44$ ms) than atypical (masculinized; $M = 680$ ms, $SE = 58$ ms), $t(24) = 2.68$, $r = .50$, $p = .01$, trajectories for typical male targets (masculinized; $M = 622$ ms, $SE = 50$ ms) were initiated at a speed not reliably different than that for atypical male targets (feminized; $M = 648$ ms, $SE = 49$ ms), $t(24) = 1.41$, $r = .28$, $p = .17$.

Spatial attraction. Mean trajectories were computed for typical and atypical male targets and for typical and atypical female targets. Plotted in Figure 4, trajectories for atypical targets reveal distinct curvature toward the competitor category. Trajectories for atypical (feminized) male targets show a continuous attraction toward "Female" relative to trajectories for typical (masculinized) male targets, and trajectories for atypical (masculinized) female targets show a continuous attraction toward "Male" relative to trajectories for typical (feminized) female targets.

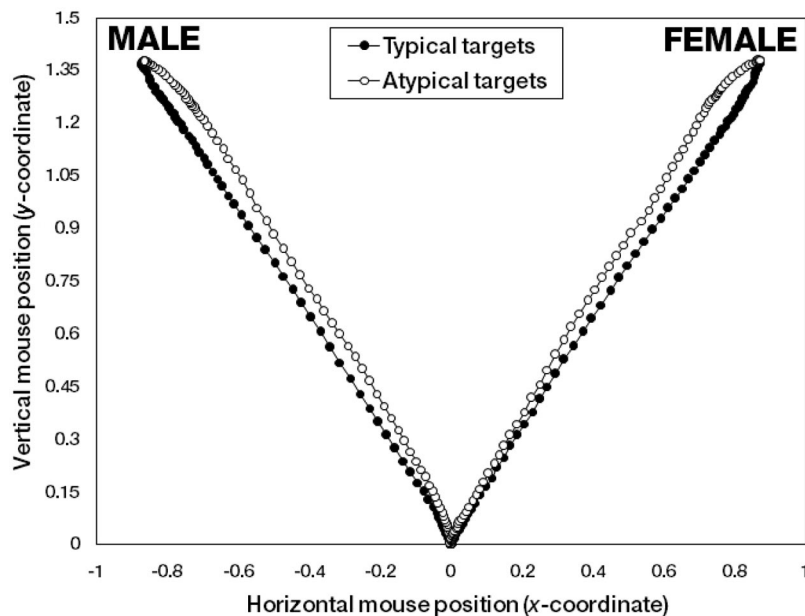


Figure 4. Mean mouse trajectories in Study 1. Trajectories for male targets are shown leftward, and trajectories for female targets are shown rightward. Trajectories for atypical (feminized) male targets exhibit a statistically reliable continuous attraction toward "Female," and trajectories for atypical (masculinized) female targets exhibit a statistically reliable continuous attraction toward "Male."

First, we assessed whether target sex or typicality had an effect on our two computed measures of trajectory curvature: curvature area and maximum deviation. We submitted curvature areas to a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 24) = 0.07$, $MSE = 0.05$, $p = .79$, $\eta_p^2 < .01$, nor did the interaction, $F(1, 24) < 0.01$, $MSE = 0.01$, $p = 1.00$, $\eta_p^2 < .01$. More critically, however, a main effect for typicality was significant, $F(1, 24) = 15.82$, $MSE = 0.04$, $p = .001$, $\eta_p^2 = .40$, such that trajectories for atypical targets were more attracted toward the competitor category on the opposite side of the computer screen relative to trajectories for typical targets. Specifically, trajectories for male targets were more attracted toward “Female” when targets were atypical (feminized; $M = 0.70$, $SE = 0.04$) relative to typical (masculinized; $M = 0.54$, $SE = 0.04$), $t(24) = 3.24$, $r = .55$, $p < .01$, and trajectories for female targets were more attracted toward “Male” when targets were atypical (masculinized; $M = 0.69$, $SE = 0.03$) relative to typical (feminized; $M = 0.53$, $SE = 0.03$), $t(24) = 4.16$, $r = .65$, $p < .001$.

Next, we submitted maximum deviations to a 2 (Target Sex) \times 2 (Typicality) repeated measures ANOVA. A main effect for sex did not reach significance, $F(1, 24) = 0.32$, $MSE = 0.01$, $p = .58$, $\eta_p^2 = .01$, nor did the interaction, $F(1, 24) = 0.04$, $MSE = 0.01$, $p = .85$, $\eta_p^2 < .01$. More critically, however, a main effect for typicality was significant, $F(1, 24) = 20.80$, $MSE = 0.01$, $p = .0001$, $\eta_p^2 = .46$, such that trajectories for atypical targets deviated more toward their competitor category on the opposite of the computer screen than trajectories for typical targets. Specifically, trajectories for male targets deviated more toward “Female” when targets were atypical (feminized; $M = 0.20$, $SE = 0.02$) relative to typical (masculinized; $M = 0.12$, $SE = 0.02$), $t(24) = 4.17$, $r = .65$, $p < .001$, and trajectories for female targets deviated more toward “Male” when targets were atypical (masculinized; $M = 0.19$, $SE = 0.02$) relative to typical (feminized; $M = 0.11$, $SE = 0.01$), $t(24) = 3.73$, $r = .61$, $p = .001$.

An analysis of trajectory divergence revealed that trajectories for atypical (feminized) male targets showed reliable spatial attraction toward “Female” relative to typical (masculinized) male targets from the 51st to the 69th time steps and from the 72nd to the 95th time steps ($ps < .05$). Similarly, trajectories for atypical (masculinized) female targets showed reliable spatial attraction toward “Male” relative to typical (feminized) female targets from the 55th to the 88th time steps ($ps < .05$).

We also created four time bins based on normalized time steps (1–25, 26–50, 51, 75, 76–101) and conducted a 2 (Typicality) \times 4 (Time) ANOVA on x -coordinates, separately for male and female targets. The means and standard errors for all possible combinations of the four time bins crossed with typicality for male and female targets appear in Table 2.

For trajectories in the male condition, this analysis yielded a significant main effect for typicality, $F(1, 24) = 9.10$, $MSE = 0.01$, $p < .01$, $\eta_p^2 = .28$, such that trajectories for atypical male targets were closer toward the “Female” response label relative to trajectories for typical male targets. This analysis also revealed a significant main effect for time (see Footnote 1), $F(3, 72) = 377.98$, $MSE = 0.02$, $p < .0001$, $\eta_p^2 = .94$, and a significant interaction, $F(3, 72) = 4.38$, $MSE = 0.01$, $p < .01$, $\eta_p^2 = .15$. Pairwise comparisons between the typical and atypical conditions at each of the four time bins revealed reliable attraction toward

Table 2
Means (and Standard Errors) for the Analyses of Variance of Time-Binned x -Coordinates in Study 2

Time bin	Male		Female	
	Typical	Atypical	Typical	Atypical
1 [1–25]	-.002 (.001)	-.001 (.001)	.001 (.001)	.002 (.003)
2 [26–50]	-.110 (.018)	-.104 (.019)	.126 (.025)	.125 (.030)
3 [51–75]	-.617 (.045)	-.563 (.044)	.625 (.037)	.573 (.050)
4 [76–101]	-.843 (.008)	-.812 (.019)	.846 (.009)	.814 (.021)

“Female” for atypical (feminized) male targets at the third, $t(24) = 2.89$, $r = .51$, $p < .01$, and final, $t(24) = 2.48$, $r = .45$, $p = .02$, time bins.

For trajectories in the female condition, the 2 (Typicality) \times 4 (Time) ANOVA on x -coordinates revealed a significant main effect for typicality, $F(1, 24) = 4.77$, $MSE = 0.01$, $p = .04$, $\eta_p^2 = .17$, such that trajectories for atypical female targets were closer toward the “Male” response label relative to trajectories for typical female targets. This analysis also revealed a significant main effect for time (see Footnote 1), $F(3, 72) = 323.86$, $MSE = 0.02$, $p < .0001$, $\eta_p^2 = .93$, and a significant interaction, $F(3, 72) = 3.94$, $MSE = 0.01$, $p = .01$, $\eta_p^2 = .14$. Pairwise comparisons between the typical and atypical conditions at each of the four time bins revealed a significant attraction toward “Male” for atypical (masculinized) female targets at the third, $t(24) = 2.39$, $r = .44$, $p = .03$, and final, $t(24) = 2.05$, $r = .39$, $p = .05$, time bins.

Discrete stage-based versus dynamic continuity accounts. Note that the spatial attraction appears continuous and graded, showing moderate curvature toward the opposite category, and does not appear extreme in the form of a sharp midflight correction. This is consistent with a dynamic continuity account. As discussed earlier, evidence for this account requires the response distributions of trajectories in the atypical conditions to be unimodal rather than bimodal. All trajectories corresponding with the atypical male condition and atypical female condition, along with their respective mean trajectories, are displayed in Figures 5A and 5B, respectively. Note that these two sets of trajectories appear to be distributed as unimodal populations in which some trajectories are relatively less attracted, some are intermediately attracted, and some are relatively more attracted toward the competitor category. Curvature areas for typical male targets and atypical male targets were together converted into z -scores within a participant and then pooled across participants. Figure 5C depicts the z distribution for atypical male targets ($n = 245$; $M = .20$; variance = 0.95; kurtosis = $-.69$; skewness = $.07$), which is similar to the z distribution for typical male targets ($n = 247$; $M = -.20$; variance = 0.88; kurtosis = $-.96$; skewness = $.26$). Bimodality coefficients (b) were computed for these two distributions. Neither distribution showed indication of bimodality (atypical male, $b = 0.428$; typical male, $b = 0.514$).

As in Study 1, curvature areas were also z -scored within each participant, separately for typical male and atypical male targets, and pooled across participants. The Kolmogorov–Smirnov test confirmed that the distribution for typical male targets and the distribution for atypical male targets were statistically indistinguishable ($D = 0.07$, $p = .56$), eliminating the possibility that the

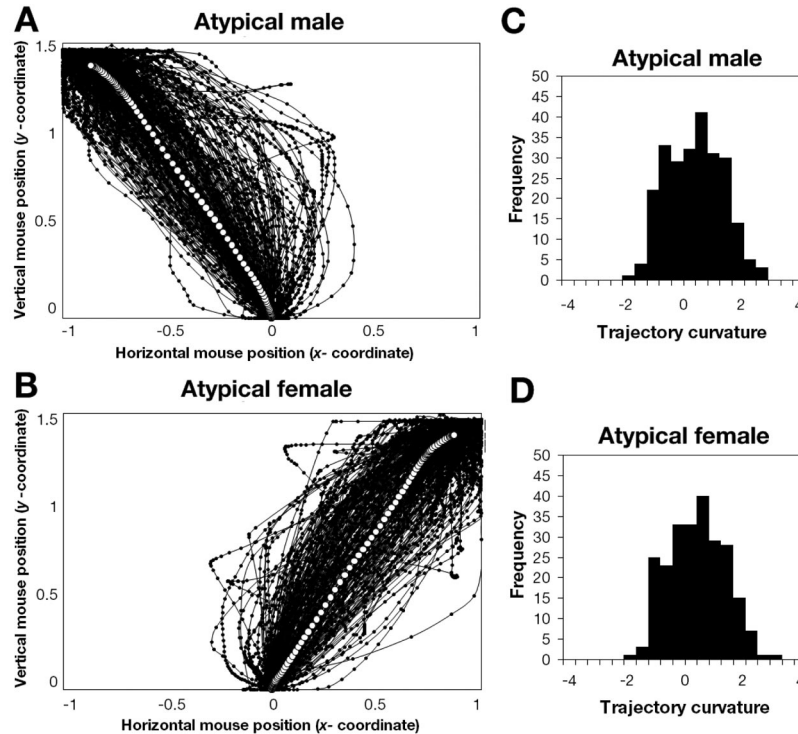


Figure 5. (A) All mouse trajectories in the atypical male condition of Study 2 are overlaid onto one graphical display, along with the mean trajectory, illustrating that the vast majority of trajectories show graded curvature toward the opposite category competitor. (B) All mouse trajectories in the atypical female condition of Study 2 are overlaid onto one graphical display, along with the mean trajectory, illustrating that the vast majority of trajectories show graded curvature toward the opposite category competitor. (C) Distribution of curvature areas in the atypical male condition of Study 2, illustrating unimodality. (D) Distribution of curvature areas in the atypical female condition of Study 2, illustrating unimodality.

distribution for atypical male targets may be selectively hosting latent bimodal features. Similarly, Figure 5D depicts the z distribution for atypical female targets ($n = 239$; $M = .21$; variance = 0.95; kurtosis = $-.67$; skewness = $.06$), which is similar to the z distribution for typical female targets ($n = 241$; $M = -.21$; variance = 0.87; kurtosis = $-.60$; skewness = $.23$). Neither distribution had any indication of bimodality (atypical female, $b = 0.424$; typical female, $b = 0.431$), and the Kolmogorov–Smirnov test confirmed that the respective shapes of the distribution for typical female targets and the distribution for atypical female targets were statistically indistinguishable ($D = 0.06$, $p = .72$), eliminating the possibility that the distribution for atypical female targets may be selectively hosting latent bimodal features.

To rule out the possibility that variability in initiation times might have confounded the spatial attraction effects, as discussed in Study 1, we examined the main effect for typicality on trajectories' curvature areas after including initiation times as a covariate in a general linear model GEE multiple regression analysis. Typicality and target sex were coded numerically and centered at 0 ($-0.5 = \text{typical}$, $0.5 = \text{atypical}$; $-0.5 = \text{male}$, $0.5 = \text{female}$). We regressed curvature areas onto typicality, target sex, the interaction between the two, and the covariate of initiation times. Initiation time did not significantly predict curvature area (unstandardized $B < 0.01$, $SE < 0.01$, $p = .94$), whereas typicality

indeed significantly predicted curvature area (unstandardized $B = 0.16$, $SE = 0.04$, $p < .0001$). Thus, the effect of typicality on trajectories' spatial attraction toward the opposite category was significant above and beyond any effect of initiation times.

Discussion

The graded and continuous attraction of real-time motor trajectories toward the competitor category across the categorization of atypical targets (feminized men and masculinized women) suggests that subtle atypical internal facial information triggered simultaneously and partially active sex-category representations that dynamically competed across the course of categorization. These spatial attraction effects for atypical targets, converging with analogous evidence obtained in Study 1 with real faces, provide evidence for the continuous dynamics underlying social categorization.

Study 3

The graded spatial attraction effects found in Studies 1 and 2 suggest that continuous dynamics underlie the process of social categorization. For these data to be fully consistent with a dynamic continuity account, it is critical to show that these spatial attraction effects are truly graded (not extreme in the form of a discrete

midflight correction) and that this gradation is induced by trajectories that are unimodally distributed (rather than bimodally distributed). Here we intend to first empirically simulate, using analogous experimental parameters as those in Studies 1 and 2, motor output that is consistent with two possibilities amenable to discrete stage-based accounts: (a) extreme curvature arising from a unimodal population comprised of all extremely attracted trajectories that are sharply corrected midflight, and (b) graded curvature spuriously arising from a bimodal distribution comprised of some “fooled” trajectories showing extreme attraction and other correct trajectories showing virtually no attraction. For the first possibility, we intend to show that the spatial attraction effects found in Studies 1 and 2, showing graded and moderate curvature toward the opposite category, appear nothing like what extreme curvature originating from a unimodal population of abrupt midflight corrections would look like. For the second possibility, we intend to successfully detect bimodality in this response distribution simulated to be bimodal, thereby demonstrating our ability to effectively detect bimodality in a response distribution similar to those in Studies 1 and 2, but that should clearly be bimodal. Such a finding would alleviate concerns that our rejections of bimodality in Studies 1 and 2 were due to a lack of statistical power or methodological sensitivity. Demonstrating that the graded spatial attraction effects of Studies 1 and 2 are inconsistent with alternative possibilities predicted by discrete stage-based accounts would strengthen our evidence for the continuous dynamics underlying social categorization.

Here we record participants’ mouse trajectories as they make sex categorizations of the typical targets (and only the typical targets) used in Studies 1 and 2. In half of trials, participants make precisely the same sex categorizations as done in Studies 1 and 2 (control condition). In the other half of trials, however, after mouse movement is initiated, the category labels suddenly turn red and switch sides (e.g., if “Male” was on the left and “Female” was on the right, “Male” would switch to the right and “Female” would switch to the left), forcing participants to discontinuously reverse the direction of trajectories (switch condition). This simulates the discontinuous replacement of one discrete stage of category activation with another discrete stage, predicted by discrete stage-based accounts. The mean mouse trajectory for switch trials should exhibit extreme curvature in the form of a sharp midflight correction. When averaging across both switch and control trials, however, this mean “combination” trajectory should spuriously exhibit what appears as continuous spatial attraction, similar to that obtained in Studies 1 and 2.

Method

Participants. Twenty-one undergraduate students participated in exchange for partial course credit or \$10.

Stimuli. Stimuli consisted of the typical male and female real faces used in Study 1 (short-haired men and long-haired women) and the typical male and female computer-generated faces used in Study 2 (masculinized men and feminized women).

Procedure. Participants engaged in the same mouse-tracking paradigm as in Studies 1 and 2, with one exception. Differing from Studies 1 and 2, participants were told that, on half of the trials, the two response buttons would suddenly turn red and the category labels would switch sides as soon as they started to categorize the target (i.e., switch trials). Participants were instructed to treat these

trials just as other trials (i.e., control trials) and nonetheless follow the correct response category if the category labels reversed sides.

Results

Data preparation and screening. We prepared and screened trajectory data using the same procedures of Studies 1 and 2. For comparison and averaging, trajectories for both switch and control trials were remapped rightward before the normalization procedures. Because of aberrant movements, nine trials were excluded. In total, 18 categorization errors were made, and these trials were discarded from subsequent analyses, resulting in a discard of 3.2% of the data.

Discrete stage-based account simulation. Three mean trajectories were computed by (a) averaging switch trials, (b) averaging control trials, and (c) averaging both switch and control trials together. These mean trajectories are plotted in Figure 6.

The mean trajectory for switch trials simulates one possibility consistent with discrete stage-based accounts, in which participants are “fooled” on all trials, causing mean motor output to exhibit a sharp midflight correction. Note that this mean trajectory for switch trials appears profoundly different from the mean trajectories for atypical targets in Studies 1 and 2 (see Figures 2 and 4, respectively), which exhibit a moderate and graded curvature toward the competitor. Thus, the graded spatial attraction evidence obtained in Studies 1 and 2 does not appear to be compatible with the possibility simulated here, consistent with discrete stage-based accounts.

The “combination” mean trajectory averaging across both switch and control trials simulates one other possibility consistent with discrete stage-based accounts, in which some of the trajectories are extremely attracted to the competitor category (akin to switch trials), whereas other trials are virtually not at all attracted (akin to control trials). As expected, this “combination” mean trajectory spuriously exhibits graded spatial attraction toward the competitor, similar to that found in Studies 1 and 2, albeit much more pronounced. All movement trajectories along with the “combination” mean trajectory are plotted in Figure 7A. Note that, very dissimilar to the trajectories in Studies 1 and 2 (see Figures 3A and 3B, and Figures 5A and 5B, respectively), approximately half of the trajectories show virtually no attraction, whereas the other half show extreme attraction, first heading toward the opposite competitor and then sharply redirecting toward the correct competitor. Curvature areas were computed, converted into z -scores within each participant, and then pooled across participants. Figure 7B depicts the z distribution of these curvature areas ($n = 813$; $M = -.03$; variance = 0.93; kurtosis = -1.36 ; skewness = .13). Note that the distributional plot hosts two distinct peaks, suggesting the presence of bimodality. Indeed, bimodality was successfully detected, $b = 0.614$. Because experimental parameters were virtually identical to those of Studies 1 and 2 (i.e., same stimuli, approximately same number of participants, same methodology, same categorizations), we argue here that if distributions for atypical targets in Studies 1 and 2 were indeed bimodal, we would have been able to successfully detect their bimodality. To ensure that the relatively larger n of the present study (because of the study design and averaging across switch and control trials) was not necessary to detect the presence of bimodality, we computed the bimodality coefficient again by keeping parameters identical except for lowering the n to a value less than those of Studies 1 and 2. Indeed, the relatively larger n of the present study was not essential for detecting bimodality, $b = 0.601$ ($n = 200$). We previously argued that the spatial attraction evidence

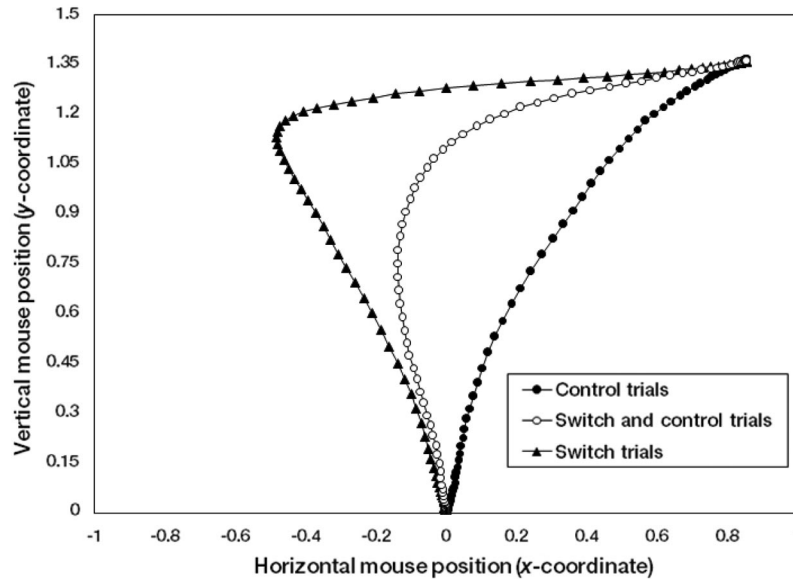


Figure 6. Mean mouse trajectories in Study 3. All trajectories are shown rightward. Trajectories for switch trials exhibit extreme attraction in the form of a discrete midflight correction. When averaging both switch and control trials into a “combination” condition, the mean trajectory spuriously produces what appears to be graded attraction.

obtained in Studies 1 and 2 was incompatible with the possibility simulated here, consistent with discrete stage-based accounts, by rejecting bimodality in the response distributions of atypical targets. Here we have validated these rejections by empirically generating this possibility and then demonstrating sufficient sensitivity to identify it should it occur.

Discussion

To cement the spatial attraction evidence obtained in Studies 1 and 2 in support of a dynamic continuity account, we used analogous experimental parameters as those in Studies 1 and 2 and simulated alternative possibilities of motor output that are consis-

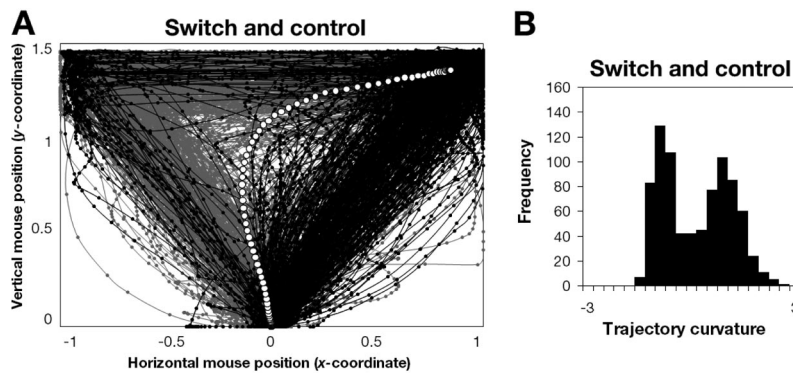


Figure 7. (A) All mouse trajectories in the switch condition (gray lines) and all mouse trajectories in the control condition (black lines) of Study 3 are overlaid onto one graphical display, along with the “combination” mean trajectory (averaging across both the switch and control conditions). Note that on approximately 5% of control trials, participants produced an extreme switch; this was likely because the task was substantially difficult, and participants confused these trials for switch trials. On the vast majority of control trials (black lines), trajectories headed directly toward the correct competitor, whereas on the vast majority of switch trials (gray lines), trajectories initially headed toward the incorrect competitor and then were sharply redirected at the correct competitor. The plot illustrates that averaging across one population of responses showing extreme attraction in the form of a discrete midflight correction (switch condition) and another population showing virtually no attraction (control condition) spuriously produces graded curvature. (B) Distribution of curvature areas in the “combination” condition, including switch and control trials of Study 3, illustrating bimodality.

tent with discrete stage-based accounts. We then demonstrated that these possibilities were incompatible with the spatial attraction effects of Studies 1 and 2. We thereby cast doubt that these effects could be consistent with discrete stage-based accounts, thus strengthening our evidence for the continuous dynamics underlying social categorization.

General Discussion

Converging evidence across three studies provides support for the continuous dynamics in real-time social categorization, consistent with the dynamic continuity account we have offered. In Study 1, we explored the dynamical nature of construing sex using representative real faces whose sex-typicality was manipulated by a sex-specifying peripheral cue, hair. Though categorizations were reliably correct, real-time motor trajectories revealed a dynamic spatial attraction toward the competitor category across the categorization of atypical targets (long-haired men and short-haired women). Thus, on their way to correctly identifying targets, participants were partially entertaining both social category representations (Male and Female) simultaneously. In Study 2, we then extended these findings of dynamic continuity to sex categorizations of precise computer-generated faces, whose sex-typicality was manipulated by morphing sexually dimorphic internal facial information. Again, real-time motor trajectories revealed a continuous spatial attraction toward the competitor category across the categorization of atypical targets (feminized men and masculinized women). Taken together, these results unveil continuous dynamics underlying the person construal process, in which multiple simultaneously and partially active representations continuously cascade into particular person categorizations. Such a notion is challenging for discrete stage-based accounts, which posit that one and only one discrete representation may be pursued by the cognitive system at any given moment in time.

If the social categorization process were indeed comprised of pure and discrete representations proceeding in stages of perfect instantiation, then it follows that motor trajectories for atypical targets could only have initially moved in one of two ways: either discretely toward the incorrect competitor (i.e., when the target “fooled” a participant) or discretely toward the correct competitor (i.e., when the target did not “fool” a participant). However, if such were the case, trajectories for atypical targets would either produce extreme attraction in the form of a sharp midflight correction (if all targets initially triggered discrete incorrect activations) or produce bimodally distributed graded attraction (if a subpopulation of targets initially triggered incorrect activations). In Study 3, we simulated these two possibilities, and demonstrated a sufficient statistical power and methodological sensitivity to rule them out. Instead, rather than discrete incorrect activations initially leading perceivers astray that are corrected by some discontinuous reanalysis, as suggested by discrete stage-based accounts, our findings suggest that these incorrect activations continuously compete and remain concurrently represented throughout the social categorization process. Thus, despite the effective categorization of others, category cues reliably linked with alternative social categorical possibilities can effortlessly produce simultaneous and graded activations across the course of construal.

The implications of these findings are wide. If “traces” of competitive activations belonging to alternative social categories

are continuously online across the course of person construal, as we have shown, these are likely to affect perceivers’ subsequent processing of social targets. For the social psychologist, the activation of a category marks a virulent chain of events to powerfully affect social behavior and interpersonal interaction. Following the trigger of a social category is the spontaneous activation of all contained stereotypes and attitudes (Devine, 1989; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Lepore & Brown, 1997), changing what we think about others (Bodenhausen, 1988; Brewer, 1988; Fiske & Neuberg, 1990), feel about them (Bargh, Chaiken, Gollwitzer, & Pratto, 1992; Fazio et al., 1986), and how we behave with and treat them (Bargh, Chen, & Burrows, 1996; Chen & Bargh, 1999). These influences often trickle down to even the lower level processes, including basic vision and memory, warping the way we quite literally perceive or envision others (MacLin & Malpass, 2001) and remember them (Hamilton & Sherman, 1994; Srull & Wyer, 1989). Further research must directly test how simultaneously and partially active category representations of unforeseen social categories (e.g., Female for a long-haired man, Male for a subtly masculinized woman) affect different aspects of social perception, evaluation, interaction, and behavior.

We do not wish to imply that the possibility of partial activations of alternative social categories is limited to specific atypical or mismatching social exemplars. Although certain perceptual cues are indeed *psychologically* atypical or mismatched (in relation to stored category information in long-term memory), these cues are expressed diversely among members and nonmembers of the social categories to which these cues belong. For instance, many women wear shorter hair, many Black individuals have lighter skin tone, and many men grow little or no facial hair and have more female-typed face morphologies. The present findings thus suggest that, for a great many of our faces, subtle category cues may set off simultaneous and graded representations of unforeseen social categories that compete continuously across person construal.

In addition to the implications for downstream social perception, two methodological contributions of the present studies are worth mentioning. First, because mouse-tracking as a continuous real-time measure of cognitive processing is only currently emerging, primarily in domains of cognitive science (Spivey, 2007; Spivey & Dale, 2004, 2006; Spivey et al., in press), efforts to validate the integrity of the paradigm are appreciable. As described earlier, to successfully support dynamical accounts using this paradigm, it is important to demonstrate that mouse trajectories show graded curvature (rather than extreme curvature) and that this gradation arises from a unimodal (rather than a bimodal) population. In Study 3, we provided an empirical simulation using the mouse-tracking paradigm that visualized what motor output would look like if a cognitive process were consistent with a discrete stage-based account: (a) extreme attraction in the form of a discrete midflight correction, or (b) graded attraction that arises from a bimodal population. We then effectively validated that this paradigm and the statistical analyses typically used in conjunction with it are sufficiently sensitive to identify spatial attraction effects that are consistent with discrete stage-based accounts. This thereby provides a paradigm validation of the mouse-tracking technique more generally, demonstrating that it can effectively distinguish spatial attraction effects consistent with both dynamical and discrete accounts. A second methodological contribution is that the present studies are the first to compute and analyze both trajectory

ries' curvature area and maximum deviation values, thereby providing an opportunity to directly compare these two indices of trajectory curvature. In Studies 1 and 2, these two measures were highly convergent, and the results of these showed negligible differences.

In sum, a growing body of social psychological research on person construal has made strides in pointing out the variety of perceptual conditions that modulate social category activation (e.g., Macrae & Bodenhausen, 2000; Macrae, Bodenhausen, Milne, & Calvini, 1999; Macrae, Bodenhausen, Milne, Thorn, & Castelli, 1997; Macrae, Hood, Milne, Rowe, & Mason, 2002) and the role of perceptual processing in achieving this activation (e.g., Bodenhausen & Macrae, 2006; Macrae & Martin, 2007; Macrae, Quinn, Mason, & Quadflieg, 2005; Mason, Cloutier, & Macrae, 2006). This work has been instrumental in beginning to crack open the *process* rather than *products* of social categorization. However, assumptions regarding the static representational format of a social category activation and a stage-based pipeline of social categorical processing have precluded examinations into the continuous dynamics underlying social categorization. Here we have provided converging evidence for a dynamic continuity account of social categorization, in which multiple simultaneously and partially active representations continuously cascade into social categorical judgments.

This dynamic continuity account may be particularly useful for emerging interests in more complex person construal, including studies of multiple social categorization (Crisp & Hewstone, 2006), in which targets are simultaneously understood along multiple category dimensions (e.g., Asian man; female doctor) or inhabit multiple categories within one dimension (e.g., multiracial targets), and including studies in the burgeoning interdisciplinary science of *social vision* (Adams, Ambady, Nakayama, & Shimojo, in press), investigating how higher order social cognition (e.g., motivations, stereotypes, social contexts) constrains the low-level vision and perception of social targets. These advances in person construal and social categorization research are beginning to require a more flexible and truly dynamic account of the construal process that allows for a fluid integration of multiple simultaneous inputs (e.g., multiple sets of perceptual cues specifying multiple social category dimensions) or multiple simultaneous sources (e.g., multiple interacting processes, such as higher order cognitive and lower level perceptual operations). Existing discrete stage-based accounts of social categorization have provided little room to allow multiple inputs and multiple processes to simultaneously and fluidly direct social perception. A dynamic continuity account, however, provides ample room for this, seeing person construal as a seamless and continuous cascade of partial products of information processing, whereby multiple inputs and multiple processes can gradually weigh in and stabilize on particular social interpretations. By allowing information from disparate inputs or sources to integrate immediately and continuously toward gradually settling on construals of others, the dynamic continuity account of social categorization may be timely for researchers needing to account for more complex person construal processes advancing in the field of social psychology and beyond.

The utility of a *continuity of mind* framework emerging from dynamicist quarters of the cognitive arena (Spivey, 2007; Spivey & Dale, 2004, 2006) is clear here. Guided by this approach, across three studies, we have exposed a more complex story underlying

person construal than previously theorized: the dynamic continuity account of social categorization. Across the process of our everyday categorizations of others lies not a series of static and symbolic representations purely instantiating themselves in and out of working memory. Instead, multiple simultaneously and partially active representations compete continuously to gradually—and not discretely—stabilize on the construals of our social world.

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Special Section titled “Spatial Reference Frames: Integrating
Cognitive Behavioral and Cognitive Neuroscience Approaches”**

The *Journal of Experimental Psychology: Learning, Memory, and Cognition* invites manuscripts for a special section on spatial reference frames, to be compiled by Associate Editor Laura Carlson and guest editors James Hoffman and Nora Newcombe. The goal of the special section is to showcase high-quality research that brings together behavioral, neuropsychological, and neuroimaging approaches to understanding the cognitive and neural bases of spatial reference frames. We are seeking cognitive behavioral studies that integrate cognitive neuroscience findings in justifying hypotheses or interpreting results and cognitive neuroscience studies that emphasize how the evidence informs cognitive theories regarding the use of spatial reference frames throughout diverse areas of cognition (e.g., attention, language, perception and memory). In addition to empirical papers, focused review articles that highlight the significance of cognitive neuroscience approaches to cognitive theory of spatial reference frames are also appropriate.

The submission deadline is February 28, 2009.

The main text of each manuscript, exclusive of figures, tables, references, or appendices, should not exceed 35 double-spaced pages (approximately 7,500 words). Initial inquiries regarding the special section may be sent to Laura Carlson (lcarlson@nd.edu). Papers should be submitted through the regular submission portal for JEP:LMC (<http://www.apa.org/journals/xlm/submission.html>) with a cover letter indicating that the paper is to be considered for the special section.