PERSON RECOGNITION FROM DYNAMIC EVENTS: THE KINEMATIC SPECIFICATION OF INDIVIDUAL IDENTITY IN WALKING STYLE

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ABSTRACT: Three experiments used Johansson's [Perception and Psychophysics, 14, 201–211 (1973)] point-light technique to investigate, whether observers could correctly recognize others from their natural and deceptive walking styles based solely on the kinematic pattern produced when walking. Participants watched pairs of video-clips of unknown young male actors and judged whether the video-clips in each pair were from the same actor or not. The pairs of video-clips consisted of one clip of an actor walking naturally across a room and one clip of an actor attempting to walk deceptively (attempting to make themselves appear considerably older than they actually were). The results from Experiments 1a and 1b demonstrated that participants were fairly accurate at recognizing when the actors in the two video-clips were the same and when they were different. In addition, an invariant of walking style (weight shift) was shown to be an important kinematic feature for the identification of walkers. Experiment 2 demonstrated that those walkers whose weight shift differed between their natural and their deceptive walk were more effective in deceiving observers about their true identity than those whose weight shift was the same in the two walks. The results are discussed in relation to the kinematic specification of identity, and the production and perception of deceptive intent.

KEY WORDS: deception; dynamics; kinematics; person recognition.

The ability to perceive the identity of other individuals has long been a topic of inquiry. Indeed, the relative ease and rapidity with which people are able to recognize and differentiate others is one of the many marvels of human perception. Individuals are able to recognize and identify

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others within crowds, over long distances and after changes to appearance (e.g., haircuts; new spectacles; aging). Past research has shown kinematic information, or body movement style, to provide sufficient information for person recognition (Baron & Misovich, 1993; Berry & Misovich, 1994; Cutting & Kozlowski, 1977; Johansson, 1973; Runeson & Frykholm, 1983, Shiffrar, Lichtey, & Chatrejee, 1997; Stevenage, Nixon, & Vince, 1999), as detailed below. Identification of others from their movement style is consistent with the ability of perceivers to recognize others across both long distances and within crowds, situations in which detailed information that is more readily associated with an individual's unique identity (e.g., facial features) is not available. Similarly, face recognition is enhanced by kinematic facial information (Christie & Bruce, 1998; Knight & Johnston, 1997; Lander, Christie & Bruce, 1999). The present research investigates, whether kinematic information is sufficient for perceivers to recognize strangers who are attempting to conceal their identity.

Researchers have employed Johansson's (1973) point-light technique to investigate whether kinematic patterns are sufficient for perceivers to identify both themselves and others (Beardsworth, & Buckner, 1981; Kozlowski & Cutting, 1977; Mather & Murdoch, 1994; Runeson & Frykholm, 1983; Stevenage et al., 1999). The technique involves videotaping individuals in tight-fitting black outfits with reflective dots or light bulbs attached to their joints. When viewed, with brightness minimized and contrast maximized, the actors are presented as arrays of point-light sources moving across a screen (monitor) in an orderly fashion, even the body silhouette is not visible to perceivers. The walkers are thereby stripped of familiarity cues such as clothes and hairstyle and structural invariants such as body contour. These point-lights are immediately recognized as human gait, however, provided that they are displayed in motion (Johansson, 1973). Much of this research has focused on the identification of categorical features of individuals (e.g., sex and age) rather than their unique identity. Observers can identify the sex of walkers at levels significantly better than chance solely from body movement patterns (Beardsworth, & Buckner, 1981; Kozlowski & Cutting, 1977; Mather & Murdoch, 1994; Runeson & Frykholm, 1983) and a specific kinematic feature of walking style, the *center of movement*, has been identified as differentiating between males (low center of movement) and females (high center of movement) (Cutting, Proffitt, & Kozlowski, 1978). A person's center of movement is defined as the reference point around which all movement in all parts of the body has regular geometric relations and can be determined from the relative swing of the hips and shoulders.

Attunement of perceivers to this feature leads to accurate perception of a walker's sex. Cutting et al. (1978) showed that the ability of observers to correctly identify the sex of synthesized male and female walkers dropped markedly when the lights corresponding to the hips and shoulders were omitted from the displays. Further, changing the center of movement in synthesized dynamic dot displays without altering the relative movement of other kinematic features (e.g., arm swing and leg movement), influenced whether participants judged the synthesized walkers to be male or female. Walkers were perceived as male when the center of movement was lower and as female when the center of movement was higher (Cutting et al., 1978; Mather & Murdoch, 1994).

In addition to this evidence for category (sex) identification solely from kinematic information, some investigations have focused more directly on whether observers are able to discriminate and identify specific individuals from walking style. Cutting and Kozlowski (1977) showed individuals to be very good at recognizing both themselves and their friends. They concluded that gait produced a synchronous pattern of movement with individually specific symmetries that observers readily perceived. Work by Barclay, Cutting, and Kozlowski (1978), and by Beardsworth and Buckner (1981) obtained similar results, supporting the view that walking style provides perceptual information about the identity of individuals. More recently, Stevenage et al. (1999) used the point-light technique to investigate whether observers were able to discriminate between, and identify, six *unknown* walkers based solely on the kinematics of gait. The results showed observers to be able to learn to identify each walker, reaching 100% accuracy within a short period of time. Furthermore, observers were just as effective in identifying the walkers under point-light conditions as they were under lighted conditions in which the walker's silhouette was also visible. Stevenage et al., (1999) accordingly suggested that human gait is a signature of personal identity and that it is a marker of identity to which the perceptual system is highly attuned. This suggestion concurs with Runeson and Frykholm's (1983) description of a "*kinematic fingerprint*" which, they argued, specifies, through bodily movement, not only a person's sex and physical identity but also their psychological and social dispositions. This claim is based within Runeson and Frykholm's (1983) *Kinematic Specification of Dynamics* (KSD) principle. The KSD principle states that the detailed spatio-temporal pattern of movement (the *kinematics*) specifies the underlying causes (the *dynamics*) of that movement. In other words, the kinematics of an event specify the factors that constrain and determine them. Given the major role that an individual's unique anatomical makeup and mechanical properties has on constraining the movement of the individual, it follows that recognition of individuals is possible from viewing their movement.

An interesting question, and the focus of the present research, arising from claims that the human gait provides an individual signature (Runeson & Frykholm, 1983, 1986; Stevenage et al., 1999) is whether changes to gait reduces the identifiability of the individual. Can individuals disguise their identity through changes to their movement style? Changes to gait have been shown to change perceptions of an individual's emotional state (Dittrich, Troscianko, Lea, & Morgan, 1996; Walk & Homan, 1984) and to an individual's vulnerability to physical attack (Gunns, Johnston, & Hudson, 2002; Johnston, Hudson, Richardson, Gunns, & Garner, 2004). Deliberate attempts to deceive perceivers through changes to gait have, however, been shown to be largely unsuccessful. Perceivers could detect, for example, when actors were attempting to walk like members of the opposite sex (Runeson & Frykholm, 1983); individuals were not able to conceal their true sex through changes to their gait. Men, for example, walking ''as if'' women do not produce the same kinematic pattern as women walking naturally. Similarly, perceivers could identify when an actor was trying to deceive them about the weight of a lifted object and could also accurately judge the real weight of the object (Runeson & Frykholm, 1983). Perceivers were not able to conceal the weight of an object through changes to the movement involved in lifting the object. This inability to deceive others suggests that the kinematic pattern associated with genuine actions and deceptive actions differs and that perceivers are sensitive to those differences. The difference between genuine and faked actions and hence the inability to deceive can be explained by the non-substitutability of actions. Different dynamic characteristics or dispositions of a person that are specified by the kinematic pattern of bodily movement are multidimensional and nonlinear (Runeson & Frykholm, 1986), the effects of changing one dynamic factor cannot be substituted for, or cancelled-out by, change in another factor. In trying to produce an unnatural movement pattern (e.g., faking a limp) one may be able to create some of the kinematic details of the genuine action but not all of the details needed to convince the perceiver that the action is genuine (Runeson & Frykholm, 1983, 1986). As any child will report, convincing one's parents that a sprained ankle is genuine in order to miss school is not an easy task; the real and faked actions just look different.

The present research investigates whether individuals are able to conceal their identity from perceivers by changing their walking gait, in this case by walking "as if" they were much older than they actually are. Based on the evidence reviewed, we predict that perceivers will be able to identify strangers from kinematic information, even when the walkers are trying to conceal their identity from observers through changes to their gait. To date, researchers have shown that observers can recognize friends or a small number of unknown walkers based solely on the kinematics of walking style (Beardsworth, & Buckner, 1981; Kozlowski & Cutting, 1977; Stevenage et al., 1999), and that observers can identity person categories (sex) despite actors' deceptive intent (Runeson & Frykholm, 1983). The reported experiments provide a more rigorous test of the ability of perceivers to identify strangers from movement. Participants in the study were required to not only recognize a larger number of briefly presented unknown walkers, but to do so under conditions of deceptive intent.

Experiment 1a

Overview

Johansson's (1973) point-light technique was used to investigate, whether observers could correctly recognize others from short silent videotaped clips. Participants were required to watch pairs of unknown male actors, one walking naturally and one walking deceptively (attempting to make himself appear considerably older than he actually was) and to judge, whether the walkers in each pair were the same or different individuals. Each of the clips was coded accordingly to a number of walking style features in order to investigate what kinematic information specifies personal identity.

Method

Part 1: Development of stimuli

Participants. Fifty male students volunteered to participate as walkers. They were between 18 and 42 years of age, between 1.69 and 2.03 m in height, and between 63.5 and 103 kg in weight.

Apparatus. The videotaping took place in the Fine Arts film studio at the University of Canterbury. A dark blue screen 5 m wide and 3 m high was erected at the front of the room. The walkers walked in front of the screen from one end to the other and back again four times. A standard

VHS video camera was centrally positioned facing the screen at an approximate distance of 5 m. A tripod in a fixed position supported the camera, and at no stage did the camera track the walkers as they walked across the front of the screen. A spotlight was positioned next to the camera and was the only light on during the filming process. The pictures were viewed on a 21-inch television monitor with contrast maximized and brightness minimized so that only the reflective dots were visible (see Figure 1).

The participants wore tight black long johns (tights), a tight black long-sleeve top, black socks, black gloves and a black balaclava. The figure hugging nature of this clothing served to minimize the possible variations in movement due to different clothing while still allowing a free range of movement and the black color eliminated any bodily reflection. Twelve 40 mm round reflective dots were positioned on the 'walking outfit' on the walker's moving joints (shoulder, elbows, hip, knees and ankles) and limb extremities (wrists and toes). For the left-hand side of the body, the dots were positioned on the outside of the body and on the inside for the right-hand side of the body.

Procedure. Walkers came to the Film Studio individually. Each walker was asked to change into the 'walking outfit' and the reflective dots were positioned appropriately. The walker was then instructed to walk as naturally as possible, at their own pace, in front of the screen from one end to the other and back again four times whilst being videotaped. Once this was completed, the walker was instructed to do the same again, except this time to impersonate a 70-year-old man. The only constraint placed on the walkers was that they were not to simulate any

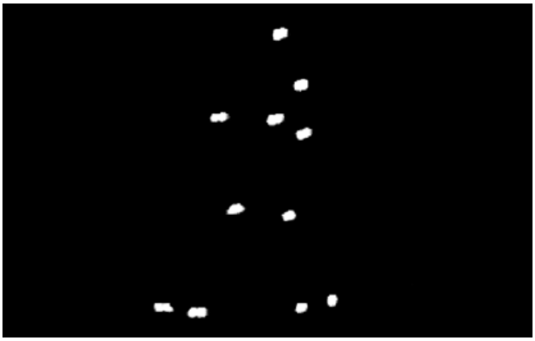

Figure 1. A still frame of a walker showing the point lights at the toes, ankles, knees, hips, wrists, elbows and shoulders.

form of walking aid (e.g., walking stick, crutch). It was made clear to each participant that the manner in which their impersonation was executed was entirely up to him and the experimenter gave no suggestions. The walkers were told to try to make their impersonation as realistic as possible and were reminded that they were trying to disguise their identity and age. Once this had been done four times, each walker was instructed to change out of the walking outfit and thanked for his participation.

Editing. The raw walker footage was edited so that the left-to-right crosses for each walker were removed and the number of passes reduced from 4 to 3. Research by Ambady and Rosenthal (1993) showed there to be no difference in perceivers' ability to detect various characteristics of actors as a function of video-clip length (5 s vs. 30 s). Given the fatigue effects associated with viewing point-light displays (Gunns, 1998) it was felt that 3 passes from each walker (approximately 17 s) was sufficient. From the edited video-clips, 30 walker pairings (WP) were generated: 15 pairs (same WPs) included 3 natural passes and 3 impersonated passes from the same walker and 15 pairs (different WPs) included 3 natural passes from one walker and 3 impersonated passes from a different walker. For the different WPs, the walkers were matched according to height and weight (mean difference in height within pairs was 1.32 cm and in weight 0.58 kg), so that the ability of perceivers to differentiate between walkers on the basis of structural (height and weight) differences was minimized. Different walkers were used for each pairing, with no walker appearing more than once. Five walkers from the initial 50 were excluded because there was no other walker who matched their height and weight. A one-second space between each pass and a four-second space between each walker was added to the videotape. The four-second gap between each walker included the letter ''A'' or ''B'' depending on whether the walker was the first (''A'') or the second (''B'') walker within a pair. Finally, an eight-second space including a participant number from 1 to 30 was added between each WP.

From these 30 WPs, five videotapes were compiled each consisting of 18 WPs (9 same and 9 different). Each pairing appeared three times over the five versions, counterbalanced in terms of both order and sequence. Each videotape ran for approximately 15 min.

Part 2: Ratings

Participants. Nineteen male and 31 female students volunteered to participate. They were between 18 and 48 years of age and had normal or corrected-to-normal vision. Nobody who participated as a walker was a participant in this part of the study.

Procedure. Participants were seated behind a desk at a comfortable viewing distance (approximately 2 m) from a 29 inch television monitor. Each participant read an information sheet giving a brief outline of the study's purpose and procedure. They were told that they would be required to watch a short video consisting of 18 WPs, where each pairing consisted of two video-clips of walkers, walkers ''A'' and ''B'', with one walker walking naturally and the other trying to deceive them about their identity by walking as if they were an old man. It was explained to them that their task was to decide whether they thought walkers A and B were the same person or not and to indicate their response on the answer sheet provided. It was also made clear that they were allowed to watch each walker make 3-passes only, but that, if required, the video tape could be paused in between each WP. Each participant was shown a WP example (this was an additional pairing and one that did not appear in any of the five versions). Once participants understood the task, the lights were turned off and they watched the videotape, rating each WP accordingly.

Results and discussion

Recognition. Initial analysis indicated no effect for sex of rater so all judgments were collapsed across this factor. On average, raters correctly identified walkers as the same or different on 69.5% of the trials. Difference tests revealed that this was significantly greater than chance (50%, $p < .05$). Rater performance was significantly better for WPs containing the same walkers than for WPs containing different walkers (75% vs. 64%, $p < .05$), however the latter is still significantly better than chance ($p < .05$).

There were, however, marked differences in recognition accuracy across the various WPs. For the different WPs, six pairs were only identified correctly at levels equal to ($n = 3$) or below ($n = 3$) chance across all observers. Similarly, for the same WPs, three pairs were consistently judged incorrectly ($n = 3$). To investigate a possible explanation for these different accuracy rates, a number of walking style features were coded for each video-clip. Comparison of these features between correctly and incorrectly identified WPs would indicate whether differences in certain walking style features were associated with errors in person recognition.

Walking style kinematics. Three raters independently coded the natural and the deceptive walking styles for each walker within the 30 pairings. Each walking clip was coded on eight kinematic features taken from

Laban analysis (Laban, 1972; Laban & Lawrence, 1967) and used in previous research investigating the kinematics of walking style (Grayson & Stein, 1981; Gunns et al., 2002; Murzynski & Degelman, 1996): stride length relative to height (1- ''short''; 7 –''long''), weight shift (primarily lateral, three dimensional, up and down, forward and back), type of walk (postural, gestural, non-specific), body movement (contralateral, unilateral), foot movement (rated on a five point scale from 1='swung' to 5= 'lifted'), arm swing, energy, and constraint (the last three were all rated using a 5-point scale; 1 = 'none', 5 = 'a lot'). Descriptions of these walking style features are in the Appendix. The three coders were experienced at coding walking styles using Laban Analysis. The order in which the video-clips were coded was such that the two clips from a single walker (natural and deceptive walks) were never consecutive clips, so that direct comparisons could not be made by the coders. In addition, the coders were unaware of the experimental hypotheses. Cronbach's alpha reliability coefficients indicated high internal consistency across raters: stride length, $\alpha = .809$, weight shift, $\alpha = 1.00$, type of walk, $\alpha = .956$, body movement, $\alpha = 1.00$, foot movement, $\alpha = .787$, arm swing, $\alpha = .866$, energy, $\alpha = .852$, constraint, $\alpha = .842$. Accordingly, the mean rating for each feature across the 3 raters was calculated and used in the subsequent analyses.

For stride length, foot movement, arm swing, constraint and energy the absolute difference between the natural walk and the deceptive walk was calculated by subtracting the natural rating from the deceptive rating within each WP (walker A–walker B). Pearson product-moment correlations between the number of correct judgments for each walker pair and these difference scores on each walking style feature were calculated separately for the same and different walker pairs. None of the resulting correlations were significant ($p > .1$), suggesting that the degree of similarity or difference in limb kinematics between the walking clips within each WP had no effect on the accuracy of person identification.

Of the three remaining kinematic features, body movement was omitted from further analysis as all walkers displayed a contralateral body movement. For type of walk and weight shift, separate 2 (WPs: same/different) $\times$ 2 (Feature Difference: none/different) ANOVAs were conducted on the number of correct judgments for each WP. If a given kinematic feature influenced the identity judgment of raters, then a significant interaction between WP and feature difference should be found, with people correctly recognizing same WPs more often when the feature was the same in both the natural and deceptive walk and correctly identifying different WPs more often when the feature was different between the natural and deceptive walks. For type of walk, there was no significant interaction between WP and type of walk, indicating that a change in type of walk had no impact on whether raters perceived WPs to be the same or different. In line with the recognition findings reported above, there was a significant main effect for WP, $F(1,26) = 6.67$, $p < .02$, with raters giving more correct responses for same than different WPs.

For weight shift, there was a significant WP by weight shift interaction, $F(1,26) = 9.36$, $p < .005$, as well as significant main effects for WP, $F(1,29) = 11.55$, $p < .002$, and feature difference, $F(1,29) = 4.55$, $p < .05$, indicating that weight shift did influence the raters' identity judgments. As illustrated in Figure 2, for same WPs, participants were equally good at correctly identifying the walkers as the same person when weight shift was the same in the natural and deceptive walk than when weight shift was different between the natural and deceptive walks (76% vs. 74%). For the different WPs, however, participants were significantly better at correctly identifying the walkers as different when weight shift was different than when it was the same in the natural and deceptive walks (70.5% vs. 51%; Tukey: $p < .006$).

The ability of perceivers to correctly identify that the two walking clips did indeed come from the same walker (same WPs) was not influenced by weight shift. The ability of perceivers to correctly identify that the two walking clips came from different walkers (different WPs) was, however, influenced by weight shift. Accuracy was greatly enhanced when the two walkers differed in their weight shift style. Weight shift, the type of body sway that occurs as a person transfers weight from one side of the body to the other when walking (Laban, 1972; Laban & Lawrence, 1967), may, then, be an important kinematic feature that specifies a persons' identity, in a similar manner to the specification of a walker's sex

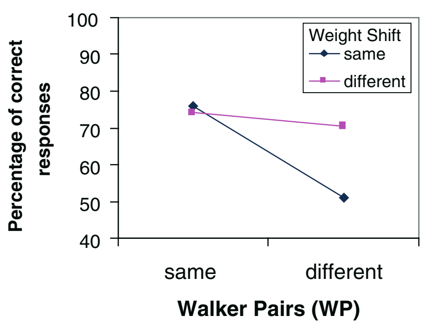

Figure 2. The percentage of correct judgments as a function of walker pairs and differences in weight shift (Experiment 1a).

by their center of movement (Cutting et al., 1978; Mather & Murdoch, 1994). The impact of weight shift is further considered in Experiment 2. Before this, however, an additional experiment was conducted to clarify the role of kinematic information in the ability of perceivers to identify strangers. Before we can conclude that recognition performance is indeed based on stimulus kinematics, we need to demonstrate that there is nothing in the static characteristics of the images (e.g., the arrangement or brightness of the point lights) that supported accurate judgments.

Experiment 1b

Overview

In Experiment 1b, a static presentation condition was added in a replication of Experiment 1a.

Method

Part 1: Development of stimuli. The video footage of walker pairs created for Experiment 1a was digitized, with 3 passes from right to left for each walker, and presented on a computer screen in Experiment 1b. Examples, can be seen at http://ione.psy.uconn.edu/~mrichardson/kinematicIdentity.htm. Three random orders of presentation were created. Each contained all 30 of the WPs from Experiment 1a. Twenty of the WPs were presented as dynamic images, as in Experiment 1a, and the other 10 WPs were presented as static images. For each walker, three static images were presented. These static images were captured from the video footage for each walker—one from the beginning of the first pass, one from middle of the second pass, and one from the end of the third pass. Each static image was presented for 6 s. A different set of 10 pairs was used as the static pairs in each of the presentation orders, such that each WP was presented in two of the presentation orders as a dynamic display and in one order as a static display.

Part 2: Ratings

Participants. Fifteen students (10 male and 5 female) volunteered to participate. They were between 18 and 32 years of age and had normal or corrected-to-normal vision. Nobody who participated in Experiment 1a as either a walker or a rater was a participant in this experiment.

Procedure. The same ratings procedure as used in Experiment 1a was employed.

Results and discussion

Recognition. On average, raters correctly identified walkers as the same or different on 54.25% of the trials, which does not differ significantly from chance (50%). Rater performance was, however, significantly better than chance when the stimuli were dynamic (60% vs. 50%, $p < 0.05$). This level of accuracy is somewhat lower than for the dynamic stimuli in Experiment 1a (69.5%) but there was a notable deterioration in the stimulus quality as a result of the digitization process. For the static stimuli, performance did not differ from chance (47.5% vs. 50%). As expected, therefore, the ability to correctly recognize the walkers was only apparent when the experimental stimuli were dynamic. A comparison of the mean accuracy rates for each WP as a static and as a dynamic image revealed a main effect, $t(29)=2.59$, $p < .05$, with greater accuracy when the same image was dynamic than static (Ms=59.68% vs. 48.86%). Accordingly, performance can be attributed to kinematic information.

Walking style kinematics. The walking style codings from Experiment 1a were employed. As in Experiment 1a, the absolute difference between the natural walk and the deceptive walk for stride length, foot movement, arm swing, constraint, and energy, was calculated by subtracting the natural rating from the deceptive rating for each WP (walker A—walker B). Pearson product-moment correlations between the number of correct judgments for each walker pair and these difference scores on each walking style feature were calculated separately for the same and different walker pairs for the static and the dynamic stimuli. As in Experiment 1a, none of the resulting correlations were significant.

For type of walk and weight shift, separate 2 (WPs: same/different) × 2 (Feature Difference: none/different) ANOVAs were conducted on the number of correct judgments for each WP, separately for the dynamic and static stimuli. There were no significant effects for type of walk, indicating that a change in type of walk had no impact on whether raters perceived WPs to be the same or different. For weight shift, there was a significant WP by weight shift interaction for the dynamic stimuli only, $F(1,26) = 10.97$, $p < .01$, as well as a significant main effect for WP, $F(1,26) = 5.61$, $p < .05$. As illustrated in Figure 3, for same WPs, participants were equally good at correctly identifying the walkers as the same person when weight shift was the same in the natural and deceptive walk than when weight shift was different between the natural and deceptive walks (65.15% vs. 59.88%). For the different WPs, however, participants

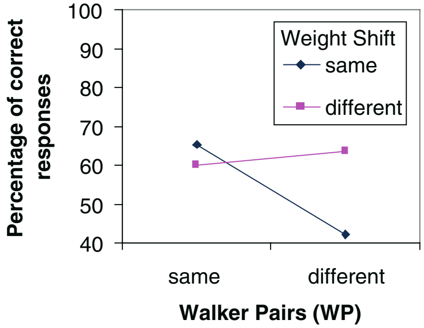

Figure 3. The percentage of correct judgments as a function of walker pairs and differences in weight shift for dynamic stimuli (Experiment 1b).

were significantly better at correctly identifying the walkers as different when weight shift was different than when it was the same in the natural and deceptive walks (63.58% vs. 42.28%; Tukey: $p < .01$).

These results replicated those from Experiment 1a. Importantly the addition of a static presentation condition clearly demonstrated that the ability of perceivers to correctly identify strangers from clips of their walking was based on kinematic information. This finding is consistent with past research that has shown face recognition to be better with dynamic than static images (Christie & Bruce, 1998; Knight & Johnston, 1997; Lander et al., 1999; Rosenblum, Yakel, Baseer, Panchal, Nodarse, & Niehus, 2002). In addition, weight shift was again identified as a kinematic feature that may specify a persons' identity. Accordingly, Experiment 2 further investigated the impact of differences in weight shift on person recognition.

Experiment 2

Overview

In an attempt to further investigate the impact of weight shift on person identification, new same and different walker pairs were created from the video-clips made for Experiment 1a. Within both the same and the different WPs, in half of the pairs the two video-clips differed on weight shift style, and in the other half they were similar on weight shift style. As in Experiments1a and b, perceivers were asked to indicate whether the 2 video-clips within each pair were from a single individual or from two different individuals.

Method

Part 1: Development of stimuli. The same video footage of participants used for Experiment 1a was employed.

Editing. As in Experiment 1a, the raw recordings were edited so that the left-to-right crosses for each walker were removed and the number of passes reduced from 4 to 3. Twenty-four walker pairings (WP) were generated: 12 included 3 natural passes and 3 impersonated passes from the same walker (same WPs), and 12 included 3 natural passes from one walker and 3 impersonated passes from a different walker (different WPs). For half of the same WPs, the single walker had a different weight shift in their natural and deceptive walks and for half, the walker had the same weight shift in their natural and deceptive walks. Similarly, in the different WPs, half comprised of two walkers with different weight shifts and half comprised of two walkers with the same weight shift. Attempts were made to match walkers in each of the WPs on the other seven coded kinematic features (stride length, type of walk, body movement, foot movement, arm swing, energy, and constraint) such that these features were the same or similar between the deceptive and natural walks. Differences in recognition accuracy are more likely, therefore, to be due to differences in weight shift than in other kinematic features. Eleven of the 24 WPs differed on a kinematic feature other than weight shift by more than half a point. Ten of these differed in constraint only (three differed by 1 point, four by 1.5 points, and three by 2 points), with the other differing in arm swing (by 1.5 points) and constraint (by 1.5 points). Although this matching is not ideal, neither constraint nor arm swing affected raters' judgments in Experiments 1a and b.

As in Experiments 1a and b, when two walkers were used in a pair, these walkers were matched according to height and weight (mean difference in height within pairs was 1.41 cm and in weight 0.85 kg). Different walkers were used for each pairing, with no walker appearing more than once. A one-second space between each pass and a four-second space between each walker was edited in. The four-second gap between each walker included the letter "A" or "B" depending on whether the walker was the first ("A") or the second ("B") walker in a pair. Finally, an eight-second space including a participant number from 1 to 24 was added between each WP. Five versions of the videotape were created to minimize possible order effects. The 24 WPs were divided into blocks of six and the order of blocks was counter-balanced across five videotapes.

Part 2: Ratings

Participants. Twenty-two male and 28 female students volunteered to participate. They were between 17 and 32 years of age and had normal or corrected-to-normal vision. Nobody who participated in Experiments 1a or b was a participant in this experiment.

Procedure. The same ratings procedure as used in Experiments 1a and b was employed.

Results and discussion. Overall, observers correctly identified walkers as the same or different on 63.38% of trials, with 59.75% correct identification in the same walker pairs and 67.0% in the different walker pairs. These identification rates were all significantly better than chance (50%, $p < .05$).

A 2 (WP: same/different) × 2 (Weight Shift: same/different) within subjects ANOVA was conducted on the total number of correct judgments made by participants for each WP. As expected, there was a significant WP × weight shift interaction, $F(1, 49) = 68.438$, $p < .0001$, with differences in weight shift influencing perceivers' judgments for both the same and different WPs as seen in Figure 4.

For same WPs, if the walker exhibited a difference in weight shift between their natural and deceptive walk, they were less likely to be correctly identified as the same walker than if there was no difference in their weight shift between the two walks (49.33% vs. 70.33%). For different WPs, the two walkers were more likely to be correctly judged as two different walkers if there was a difference in weight shift between the natural and deceptive walks than if there was no difference in weight shift (68.0% vs. 45.67%).

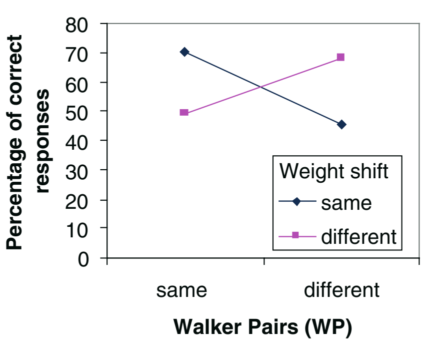

Figure 4. The percentage of correct judgments as a function of walker pairs and differences in weight shift (Experiment 2).

In this Experiment, similarity or difference in weight shift influenced the accuracy of observers' person recognition for both same and different WPs. These findings provide supporting evidence for the suggestion, based on the findings from Experiments 1a and b, that weight shift is an important kinematic feature of walking style that can be used by observers to identify, or recognize, unknown others.

General Discussion

The present experiments demonstrated that the kinematic information provided by walking style can support the recognition of strangers. These findings extend those of Cutting and Kowlowski (1977) and Stevenage et al. (1999) by demonstrating that recognition of strangers as well as of close friends was possible solely from kinematic information. Experiment 1b emphasized the importance of dynamics in recognition accuracy; perceivers performed at a level above chance when presented with dynamic images but at chance level when presented with static images taken from the video-clips. These results from whole body kinematics parallel those seen for facial kinematics in which face matching was significantly better with dynamic than static facial point-light displays (Rosenblum et al., 2002).

Moreover, the recognition of walkers from kinematic information was still reliable even when the walkers attempted to deceive the observers as to their identity. This result extends Runeson and Frykholm's (1983) finding that categorical identity (sex) could be determined from kinematics when actors were attempting to deceive as to their sex. Perceivers in our experiments were able to detect the unique dynamics of others from the kinematics of walking style and the specificity of those dynamics was not obscured when deceptive movement was employed. The overall accuracy levels in our experiments were somewhat lower than in previous similar studies (Cutting & Kozlowski, 1977; Stevenage et al., 1999), but this may reflect a greater difficulty in recognizing unknown persons than close friends and a greater difficulty in person recognition when the actors have deceptive intentions than when they do not. The findings do provide support for the notion of the individual's unique kinematic fingerprint (Runeson & Frykholm, 1983; Stevenage et al., 1999). It should be noted, however, that participants in our research were only required to make same or different judgments within given pairs of walkers. It is possible that accuracy would not be as high if participants were required to identify a given walker from a group of strangers.

Despite the relatively high level of recognition accuracy, the observers in the dynamic stimulus conditions did still make some identification errors, either perceiving a natural and a deceptive walk as coming from a single individual rather than from two individuals or vice-versa. The analysis of walking style features in Experiments 1a and b indicated differences or similarities in weight shift might account for errors in person recognition. The creation of pairs of walking clips based on similarity or difference in weight shift in Experiment 2 further emphasized the role of this kinematic feature in the specification of individual identity. The finding that perceivers were less able to identify walkers as the same when weight shift differed between an actor's natural and deceptive walks indicates that the ability to deceive depends, at least partially, on the ability of the deceiver to alter relevant movement features.

In the reported experiments, the ability of actors to deceive was a function of their ability to change their weight shift across walking conditions. Given that our research included only one manipulation of deceptive intention—attempting to appear older—we cannot conclude that weight shift will be influential in all attempts at deception or attempting to conceal one's identity. Past research that has asked individuals to walk as though a member of the other sex, which has shown high accuracy for identifying the actual sex of the walkers, did not consider differences or similarities in specific walking style features and whether these could explain the pattern of errors made by perceivers (Runeson & Frykholm, 1983). It is possible that for different deceptive actions different kinematic features will be especially relevant. In addition, our walkers were all male and so we cannot conclude that differences in weight shift would similarly affect person recognition for female walkers, although there is no reason to hypothesize that different kinematic features would be influential for male and for female walkers. Further, it is not assumed that actors have awareness of the specific kinematic features they change in order to successfully deceive others. In fact, it is likely that individuals are unaware of the kinematic features that specify certain dynamics (Gunns, 1998; LeJeune, 1977; MacDonald, 1975), although individuals can be trained to change certain kinematic features in order to change specific dynamics. For example, Johnston et al. (2004) showed that training walkers to change certain kinematic features of their walking style could reduce their vulnerability to stranger attack.

Another caveat that needs to be acknowledged when interpreting the present findings is that we only considered the ability of actors to deceive observers as to their true identity. We did not consider whether the actors could successfully convince the observers that they were old. Our observers knew that all of the walking clips came from young men who were, in some cases, attempting to walk in a manner consistent with their being elderly. We are, therefore, unable to comment on the extent to which our actors could actually deceive perceivers as to their age, although our video-clips could be used to address this question. For our research question regarding person identification, the age manipulation in our videotaping was simply a means of creating two walking-style clips from each walker.

In addition to considering the ability of actors to deceive perceivers as to their identity, future research should also consider characteristics of the perceiver. The ability of an observer to perceive an actor's deceptive intent is an issue of sensitivity, or attunement. In the case of observing others, the ability to correctly identify the underlying dynamics, including deceptive intent, of an actor is directly related to the observer's attunement to the kinematics that specify the actual identity and the deceptive intentions of the actor. Consequently, the greater the observer's attunement to the relevant information, the less likely they are to be deceived as to the actor's identity.

In summary, the present research demonstrated that people can correctly recognize others from the kinematics of walking style, even when the actors are attempting to disguise their identity. Furthermore, weight shift has been proposed as a critical kinematic feature in the correct identification of strangers.

Appendix Walking Style Features

Coding based on Laban analysis (Laban, 1972; Laban & Lawrence, 1967).

Stride Length

1—very short stride length relative to height through.
5—very long (stretched) stride length relative to height.

Weight Shift

- Primarily lateral motion—side-to-side motion.
- 3-D—a smooth motion involving the whole body, centered around the hips.
- Primarily up-and-down motion—a ''bounce'' in the walk.
- Primarily forward-and-back motion—a sway in the walk, shifting weight from the front to the back of the foot with each stride.

Type of Walk

- Postural motion—involving the whole body.

- Gestural motion—motion of separate parts of the body.

Body Movement

- Contralateral motion—motion of the two sides of the body in counterpoint.
- Unilateral motion—movement of one side of the body at a time.

Foot Movement

1—a "swinging" heel-to-toe motion.
5—a raising and lowering of the whole foot as a single unit.

Arm Swing

1—none.
5—extensive.

Amount of Energy

1—minimal, very lethargic.
5–very energetic.

Degree of Constraint

1—very constrained, tight motion.
5—very relaxed, loose.

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