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First impressions: Gait cues drive reliable trait judgements

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ABSTRACT

Personality trait attribution can underpin important social decisions and yet requires little effort; even a brief exposure to a photograph can generate lasting impressions. Body movement is a channel readily available to observers and allows judgements to be made when facial and body appearances are less visible; e.g., from great distances. Across three studies, we assessed the reliability of trait judgements of point-light walkers and identified motion-related visual cues driving observers' judgements. The findings confirm that observers make reliable, albeit inaccurate, trait judgements, and these were linked to a small number of motion components derived from a Principal Component Analysis of the motion data. Parametric manipulation of the motion components linearly affected trait ratings, providing strong evidence that the visual cues captured by these components drive observers' trait judgements. Subsequent analyses suggest that reliability of trait ratings was driven by impressions of emotion, attractiveness and masculinity.

1. Introduction

Observers tend to agree with each other when making personality trait judgements on 'thin slices of behaviour', such as seeing someone in person for 10 s (Albright et al., 1997) or watching 2-s long silent video clips of behaviour sequences (Ambady & Rosenthal, 1993). This is known as consensus at zero acquaintance (Albright, Kenny, & Malloy, 1988). Most studies using a zero-acquaintance paradigm give observers access to static information that may have an impact on perceived personality; for instance, a neat attire and being well groomed have an impact on perceived conscientiousness and extraversion (Albright et al., 1988). However, some studies have reported consensus at zero acquaintance based on point-light stimuli (Brownlow, Dixon, Egbert, & Radcliffe, 1997; Heberlein, Adolphs, Tranel, & Damasio, 2004; Montepare & Zebrowitz-McArthur, 1988). In this type of stimuli, information about the static form of the body is greatly reduced to the motion of points representing body joints (e.g., knees and elbows). Point-light displays, initially developed by Johansson (1973), therefore constitute a popular form of impoverished visual stimuli to investigate the contribution of motion (kinematic and form-from-motion) cues to observers' ratings of personality and other trait impressions. Previously, it has been shown that observers reliably judge transient states such as emotions from point-light displays showing movements of the whole-body (Atkinson, Dittrich, Gemmell, & Young, 2004; Dittrich, Troscianko, Lea, & Morgan, 1996; Heberlein et al., 2004) or of the arm alone (Pollick, Paterson, Bruderlin, & Sanford, 2001). They also reliably judge stable characteristics such as identity (Cutting & Kozlowski, 1977; Loula, Prasad, Harber, & Shiffrar, 2005) and sex (Kozlowski & Cutting, 1977) from point-light whole-body motion.

Using subjective measures, some attempts have been made to describe the motion characteristics that influence person perception, such as 'youthfulness' driving impressions of the perceived power of point-light walkers (Montepare & Zebrowitz-McArthur, 1988). However, no

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previous studies have identified motion parameters for personality ratings using computational analyses of motion data of walking targets. The main aims of the current studies are to replicate an consensus of zero acquaintance using point-light walker stimuli and to identify motion characteristics that drive first impressions of personality traits.

Despite the reliability of trait impressions, people are not always accurate in their judgements. Whilst some studies report a 'Kernel of Truth' in trait impressions (Berry, 1990; Borkenau, Mauer, Riemann, Spinath, & Angleitner, 2004; Penton-Voak, Pound, Little, & Perrett, 2006), plenty of evidence points towards unrelated, and often transient, cues driving personality judgements, such as physical attractiveness (Dion, Berscheid, & Walster, 1972; Feingold, 1992; Jones, Little, Burt, & Perrett, 2004) or emotions (Knutson, 1996; Montepare & Dobish, 2003), which shows that people are not infallible in their judgements. However, consensus at zero acquaintance remains an interesting topic of study independent of the Kernel of Truth hypothesis and the lack of accuracy by no means diminishes the importance of our study. Trait impressions are automatic (Asch, 1946; Engell, Haxby, & Todorov, 2007; Willis & Todorov, 2006) and important social decisions such as voting choice have been found to be linked to such impressions even though the traits have little to no relation to a politician's suitability (Kramer, Arend, & Ward, 2010; Little, Burriss, Jones, & Roberts, 2007; Todorov, Mandisodza, Goren, & Hall, 2005). Implicit trustworthiness judgements based on photographs have also been found to cue strategic decision making in trust games, despite no actual relationship between perceived trustworthiness and likelihood of reciprocal behaviour (van't Wout & Sanfey, 2008).

Consensus at zero acquaintance based on visual stimuli alone means that discernible visual characteristics communicate trait impressions and it should thus be possible to extract these. Some studies have indeed succeeded in identifying static visual cues for trait judgements, such as facial symmetry in photographs (Noor & Evans, 2003) or low spatial frequencies (Bar, Neta, & Linz, 2006). However, describing purely *dynamic* cues for trait ratings has proven more difficult. Ambady and Rosenthal (1993) found agreement amongst judges of personality traits based on 30-s silent video clips. Interactions with the environment ('fidgeting' with hands or objects) as well as facial expressions (smiling and frowning) were the only parameters that predicted personality or teacher effectiveness ratings. Montepare and Zebrowitz-McArthur (1988) found high reliability for personality trait ratings of point-light walkers (e.g., dominance, boldness and approachability), despite any evidence of accuracy in the trait ratings. They identified no motion parameters predicting these personality ratings. Rather, they used subjective gait ratings, which may be confounded with trait ratings. High inter-trait scale correlations are common in rating studies (e.g., Oosterhof & Todorov, 2008), and a 'what is beautiful is good' bias, a so-called Halo Effect, is common when making judgements of strangers in general (Dion et al., 1972).

In contrast to studies examining relations between trait ratings alone, we aimed to discover which objective aspects of the physical stimulus – specifically, which visual cues specified in the kinematics of people's gait – drive personality trait judgements. Although kinematic analyses of gait and other whole-body movement have been used to discover which visual cues drive perception of sex (Kozlowski & Cutting, 1977; Mather & Murdoch, 1994; Troje, 2002), vulnerability (Gunns, Johnston, & Hudson, 2002; Johnston, Hudson, Richardson, Gunns, & Garner, 2004) or emotion (Pollick et al., 2001; Roether, Omlor, Christensen, & Giese, 2009), we here present for the first time a kinematic analysis of personality trait judgements.

In Study 1 we assessed the reliability of observers' judgements of a range of personality traits based on the Big Five (Costa & McCrae, 1992) when observers were shown one gait cycle of point-light walker stimuli. We measured the personality of the walkers from whom the point-light displays were derived in order to assess whether observers were accurate in their trait judgements; that is, if trait ratings corresponded to self-reported personality traits of the target walkers. Using principal components analysis (PCA), we then reduced the motion data captured from the walkers (i.e. the 3D coordinates of the point-light markers over time) to a smaller set of components (Troje, 2002) and identified motion parameters that are associated with the perceived personality traits. We also assessed the link between the walkers' own personality traits and their gait using these same motion parameters. In Study 2, in order to validate the correlation between motion parameters and personality judgements, we carried out two experiments to assess how parametric manipulations of these motion parameters influence personality ratings. Finally, in Study 3, we collected further trait ratings to assess whether the personality impressions were driven by judgements of age, attractiveness, emotion, gender, or health.

Methods other than PCA exist for describing physical features of visual body stimuli. For example, in addition to subjective ratings, both posture cues, such as joint angles, and movement cues, such as a change in the linear weights of different body parts relative to neutral walking, have been found to classify emotional expressions (Roether et al., 2009). We chose Troje's (2002) PCA-based model for reducing point-light walker stimuli into a small number of motion parameters. Troje found that four components explained 98% of the variance in point-light walker motion-capture data, and that these components could be used to classify gender. We therefore investigated whether similar components extracted from our point-light walker data could further cast light on other individual differences, such as personality.

1.1. Generating point-light walkers

Twenty-six targets (14 female and 12 male; mean age = 19.7, *SD* = 2.6) were recruited from Durham University. Apart from three males, all participants were undergraduate psychology students who took part in the experiment in exchange for partial course credit. The targets were sampled from a different year-group than the observers tested in Studies 1, 2 and 3, to avoid possible effects due to familiarity with the gait of friends or other peers. Further selection criteria ensured that targets had little, or no, acting experience. To add power to analyses of accuracy in trait ratings, a range in the target individuals' personality traits was ensured through a selection procedure whereby prospective targets filled in the NEO FFI SF personality questionnaire (Costa & McCrae, 1992). The selection procedure resulted in target scores ranging, in average, from 29th to 72nd percentile in relation to the general population corrected for gender. See Supplementary Fig. S1.

The target individuals' whole-body walking movements were captured using a VICON system (Oxford Metrics, UK). Eighteen retro-reflective markers were attached to targets' joints at the targets' feet, knees, hips (four markers), torso, shoulders, head, elbows, wrists and hands. Three-dimensional positions of these markers were recorded at a frequency of 100 fps. Targets were instructed to walk naturally, at their own desired pace, between two spots approximately eight metres apart. We selected one whole walk cycle from the middle of this sequence. The starting point was defined by one foot touching the floor; cycles were selected such that they could be looped continuously without looking 'jerky'. However, to avoid the possibility that some stimuli looked smoother than others, a 150 ms black frame was added to the end of each clip. Since targets' speed differed, the number of frames was not equal (mean number of frames = 114.4, *SD* = 11.2).

To reduce the amount of static information available to observers, the number of markers in the final 2D stimuli was reduced to 13, a number commonly used in whole-body point-light displays (e.g., Dekeyser, Verfaillie, & Vanrie, 2002; Loula et al., 2005; Prasad & Shiffrar, 2009). This involved averaging the two left and two right hip markers to create a single virtual left and a single virtual right hip marker. This meant that the placement of the hip markers was to a degree standardised: the markers were 'inside' the hips of the targets, thus reducing variability of perceivable waist circumference. For the other 11 markers selected, one was from the target's head, and one from each shoulder, elbow, wrist, knee and foot. In the final point-light video clips, translation was removed and the targets appeared as if walking on a treadmill, facing diagonally towards the right. The points were white on a black background.

2. Study 1: personality ratings of unmodified point-light walkers

In Study 1, the point-light stimuli were used to obtain personality ratings of the 26 target walkers from observers. These rating data were subsequently compared to motion data parameters derived through Principal Component Analysis (PCA).

2.1. Experiment 1: obtaining the personality trait ratings

2.1.1. Method

Twenty-four observers were used (13 female and 11 male; mean age = 19.3, *SD* = 0.9). All participants were undergraduate psychology students who took part in the experiment in exchange for partial course credit.

Psyscope X (see http://psy.ck.sissa.it) was used to present stimulus movie clips on a 19'' LCD screen with a refresh rate of 60 Hz. Participant responses were collected using the top row number keys of a standard QWERTY keyboard.

The stimuli were point-light walkers created as previously described. The stimuli subtended approximately 22° of visual angle (vertical) at a viewing distance of 40 cm. Observers rated one-cycle point-light walkers on six rating scales. Five of these were related to the Big Five: adventurousness (measuring openness to experience), extraversion, neuroticism, trustworthiness (measuring conscientiousness) and warmth (measuring agreeableness). To this a sixth scale, approachability, was added, because of its frequent use in the person perception literature (Adolphs, Tranel, & Damasio, 1998; Frigerio et al., 2006; Montepare & Zebrowitz-McArthur, 1988). All 26 stimuli were rated on a given scale before the next scale appeared, creating a total of six blocks. Block order was randomised, as was the order of stimuli within the block. Observers were instructed to go with their 'gut' feeling and to think of the traits as independent of each other. During a trial, the walker was looped with an added 150 ms break after each walk cycle. The stimulus was displayed until observers responded. Once a clip had been rated, the next appeared without delay.

2.1.2. Results and discussion

Table 1 shows the inter-rater reliability for the six scales. Good reliability was found, with all Cronbach's $\alpha > .80$, apart from warmth, at .74, which is still considered acceptable inter-rater agreement. The high reliability fits with previous studies showing consensus at zero acquaintance (Albright et al., 1988; Engell et al., 2007; Kenny, Albright, Malloy, & Kashy, 1994) and shows that some physical features of the stimuli, visible to observers, drive trait impressions. High agreement was not due to recognition of sex of target driving the trait judgement, as agreement was high also within each sex (see Table 1).

2.2. Cues for personality trait judgements

The high reliability of the trait judgements prompted an investigation of which factors might be driving the impressions. We separated this investigation into two parts: first, we extracted motion parameters that may be associated with perceived personality; secondly, we assessed whether the self-reported personality traits of the target walkers were associated with the trait ratings.

Table 1
Inter-rater reliability (Cronbach's α) of personality trait ratings.

Trait scale	Female targets	Male targets	Across targets
Adventurousness	.94	.92	.93
Approachability	.77	.84	.80
Extraversion	.91	.92	.91
Neuroticism	.82	.82	.90
Trustworthiness	.75	.85	.82
Warmth	.62	.81	.74

2.2.1. Motion parameters associated with perceived personality

A range of motion parameters was extracted from the point-light walker stimuli. The walker stimuli were analysed individually: each of the 26 motion data files used to generate the point-light stimuli was run through a separate Principal Component Analysis (PCA). Only the 13 markers that were used to create the point-light stimuli were retained, to limit the possibility of extracting parameters that were unavailable to observers. The 3D coordinates of each marker over time were used in the PCA, thus resulting in 39 variables, each line corresponding to one frame, following the procedure of Troje (2002). The analysis showed that two components on average sufficed to explain 94.3% of the data (of which the first accounted for 87.7%), and including a third component increased this to 98.7%.

For each principal component of each walker file, the component scores could be fitted by a sinusoidal function with a given amplitude, frequency, and phase. The goodness of fit for all three components was strong (across motion-file average $R^2_{PC1} = .99$; $R^2_{PC2} = .92$; $R^2_{PC3} = .91$). Since the third component accounted for only 4.4% of the variance, this component was not included in further analyses because its discernible impact on the movement was minimal. Fig. 1 shows the scores and sinusoidal fit for the first two PCs of an example walker.

The two retained principal components were further summarised by only two sinusoidal parameters: amplitude and frequency. The resulting four motion-descriptive parameters were thus employed for analyses on trait impressions. The phase of a sinusoidal function is simply related to the arbitrary decision of where that walk cycle is started and which direction the walker was headed, and is therefore excluded from all further analyses.

The amplitudes of PC1 and PC2 showed potential in predicting trait impressions (see Table 2); correlations between trait impressions and other components were nil (data not reported). The amplitude of PC1 was correlated with adventurousness, extraversion, trustworthiness and warmth. The amplitude of PC2 correlated negatively with neuroticism ratings ($p = .018$) although this did not survive a Bonferroni correction for multiple comparisons.

Table 2
Correlations (Spearman) between component amplitude and personality trait ratings.

Trait scale	PC1	PC2
Adventurousness	.59**	−.27
Approachability	.22	.29
Extraversion	.50**	−.18
Neuroticism	.07	−.56*
Trustworthiness	.63***	.01
Warmth	.62***	.12

* $p < .05$.
** $p < .01$.
*** $p < .001$.

In order to obtain a description of the motion parameters, we collected subjective motion descriptions using an Effort-Shape analysis (Gross, Crane, & Fredrickson, 2010), whereby a separate group of 26 observers rated the point-light walkers on scales anchored with motion-descriptive adjectives (see Table 3 for descriptors, see Supplementary material for more complete details). PC1 Amplitude was associated with use of personal space, with expanding torso and limbs moving away from the body. PC2 Amplitude was negatively correlated with Time, Space and Flow, thus associated with a *leisurely*, *relaxed* walk with more *diffuse* use of space (see Table 3).

2.2.2. The relationship between self-reported and perceived personality traits

The consensus across observers in the trait impressions may be driven by the actual personality traits of the targets

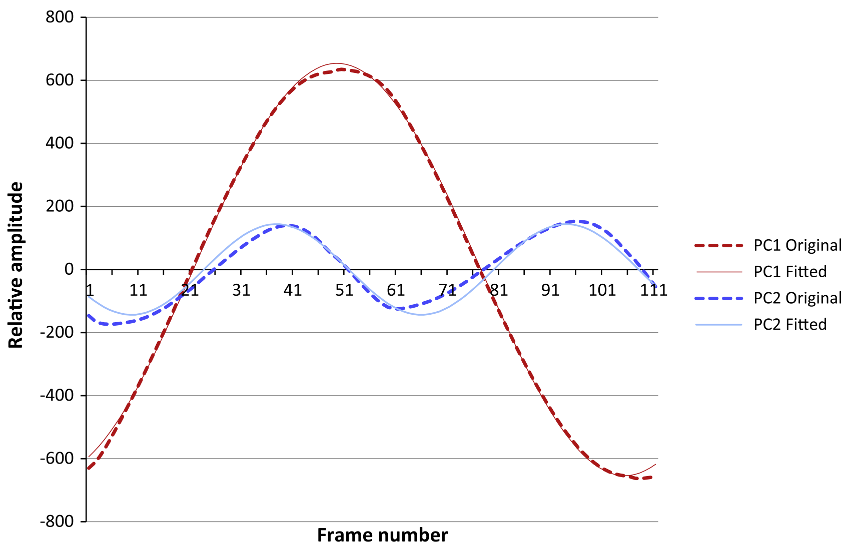

Fig. 1. Scores from two components (dotted) as well as sinusoidal fits (solid) of an example walker. PC1 is depicted in red; PC2 in blue. For this walker R^2 for PC1 > .99, R^2 for PC2 = .94. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Effort-shape factors with descriptors and correlations (Spearman) with component amplitudes.

Effort-shape factor	Descriptors presented to observers		Component	
	Left-anchor	Right-anchor	PC1	PC2
Torso	Contracted, bowed, shrinking	Expanded, stretched, growing	.52**	−.11
Limb	Moves close to body, contracted	Moves away from body, expanded	.40*	.05
Energy	Light, delicate, buoyant	Strong, forceful, powerful	.03	−.34
Space	Indirect, wandering, diffuse	Direct, focused, channeled	.20	−.54**
Time	Sustained, leisurely, slow	Sudden, hurried, fast	.30	−.52**
Flow	Free, relaxed, uncontrolled	Bound, tense, controlled	−.18	−.67***

* $p < .05$.
** $p < .01$.
*** $p < .001$.

being reflected in their gaits. There are advantages in being able to accurately predict personality traits based on non-verbal behaviour (Barrett, Todd, Miller, & Blythe, 2005) and recent studies lend support to the idea that people are accurate in their ratings of certain traits based on non-verbal cues from photographs of faces (Penton-Voak et al., 2006) or video clips (Borkenau et al., 2004). To assess this possibility we correlated the self-reported personality scores of the targets with the observers' trait ratings. This approach is the most common for studies that assess the Kernel of Truth hypothesis (Borkenau & Liebler, 1992; Borkenau et al., 2004; Penton-Voak et al., 2006). The Big Five scores from the NEO FFI SF (Costa & McCrae, 1992)—administered to targets prior to the motion capture procedure—were used as self-reported traits, and these were evaluated in relation to their corresponding rating scales from the observers (see Section 2.1.1). An accurate judgement would be made if the trait rating of, say, neuroticism correlated with self-reported neuroticism. The data for male and female target individuals were analysed separately to avoid inflated correlations; gender differences in self-ratings of personality have been found to coincide with social stereotypes (Costa, Terracciano, & McCrae, 2001).

The findings indicated no validity of trait judgements, in that no significant within-trait correlations between self- and peer-ratings were found: coefficients ranged from −.17 (openness to experience) to .23 (conscientiousness). It appears that trait impressions based on motion data of point-light walkers are reliable but not valid: observers agree with each other about which walkers look, say, extroverted or conscientious, but their impressions do not correspond to how the targets rated themselves. It could be that the Kernel of Truth hypothesis only holds for other types of information (e.g., verbal or facial stimuli). Even with other types of stimuli, however, there is mixed evidence for the Kernel of Truth hypothesis, and the impact of transient cues on trait impression (Knutson, 1996; Montepare & Dobish, 2003) may indicate that this is highly context-dependent.

2.2.3. The relationship between self-reported personality traits and gait

Even though people are not able to accurately predict personality traits from gait alone, this does not imply that there is no link between *self-reported* personality traits and gait. For instance, motion parameters associated with certain personality traits might not be discernible to observers, or they are discernible but observers do not (correctly) employ them when making their judgements. To explore this possibility, we investigated links between the sinusoidal motion parameters and the self-reported trait scores.

Male and female target walkers were treated separately for the analyses. Females showed no significant correlations between any of the Big Five personality traits and the sinusoidal parameters extracted from the motion-capture files (all *ps* > .05). Extraverted males appeared to have a reduced PC1 amplitude, $\rho = -.72$, $p = .009$. However, this did not survive a Bonferroni correction for multiple comparisons. Males who rated themselves open to experience had a markedly lower PC2 amplitude, $\rho = -.90$, $p < .0001$. Although this correlation survived Bonferroni correction, the corresponding correlation for female target walkers was nil ($\rho = -.02$, $p = .93$) so it is unclear whether this is simply an artefact in the data. A follow-up study is needed to verify this.

In summary, using PCA we identified motion-related visual cues that drive observers' reliable judgements of personality from gait, with the first two principal components together accounting for 94.3% of the original motion capture data. Yet we found no evidence of associations either between these motion parameters and self-reported personality or between self-reported and perceived personality.

3. Study 2: influencing perceived personality by manipulating point-light walkers

We have shown that observers agree with each other when they are asked to rate point-light walkers on a range of personality traits and that this consensus can be traced to motion parameters of the motion data. However, it is possible that the point-light stimuli still contain static information and that such static cues might be confounded with the motion parameters. To address these potential confounds, two further experiments were carried out in which the PCs of point-light walks were systematically manipulated to see how these motion parameters affected observers' ratings. The walker stimuli used in Experiment 1 were manipulated by multiplying the amplitude of the scores of PC1 or PC2 by given constants. Modified walker stimuli were then created based on the first four components only. Although two components sufficed to explain

94.3% of the variance in the data, we included the third and fourth component in order to make the modified walker stimuli more 'natural-looking'.

3.1. Experiment 2A: manipulation of PC1

In Experiment 2A, we scaled the amplitude of the coefficients, and thus of the scores, of the first principal component (PC1) by −20% to +20% in 10% increments, thus creating five new versions of each point-light walker. A 0% scaling represents the original score for PC1.

3.1.1. Method

Twenty-six new observers (20 female and 6 male; mean age = 19.4, *SD* = 0.8) took part in this experiment. All participants were undergraduate psychology students taking part in exchange for partial course credit. Each block contained 130 stimuli, consisting of the five versions of each walker presented in a random order. Further details of the methods were identical to those in Experiment 1.

3.1.2. Results and discussion

Inter-rater reliability was high (see Supplementary Table S1), with most coefficients suggesting strong agreement, with the exception of approachability ($\alpha = .66$). As can be seen in Fig. 2, manipulation of PC1 had an impact on trait ratings. A multivariate analysis of variance (MANOVA) treating the 26 walkers as random effects confirmed this: There was a main effect of manipulation, $F(24,332) = 14.58$, $p < .001$, partial eta-squared (η_p^2) = .47. This was significant for adventurousness, $F(4,100) = 121.88$, $p < .001$, $\eta_p^2 = .83$, extraversion, $F(4,100) = 127.61$, $p < .001$, $\eta_p^2 = .84$, trustworthiness, $F(3.16,79.04) = 4.80$, $p = .003$, $\eta_p^2 = .16$, and warmth, $F(3.35,83.64) = 11.92$, $p < .001$, $\eta_p^2 = .32$. For all these scales, larger amplitudes resulted in higher trait ratings. As expected, there was no effect of PC1 on approachability ($p = .60, \eta_p^2 = .03$) or neuroticism ($p = .56, \eta_p^2 = .03$). This therefore coincides with the findings from Study 1. Trend analyses showed that there was a linear effect of manipulation on the ratings for all four trait scales: adventurousness $F(1,25) = 412.10$, $p < .001$, $\eta_p^2 = .94$; extraversion, $F(1,25) = 300.79$, $p < .001$, $\eta_p^2 = .92$; trustworthiness, $F(1,25) = 10.12$, $p < .01$, $\eta_p^2 = .29$; and warmth, $F(1,25) = 34.20$, $p < .001$, $\eta_p^2 = .58$. There were no significant higher-order trends.

3.2. Experiment 2B: manipulation of PC2

A similar procedure as in Experiment 3A was carried out for PC2; that is, the amplitude of the score was manipulated in order to see what effect this had on perceived personality traits. PC2 accounted for far less variance in the data than did PC1 (6.6% versus 87.7%) and, in line with this, manipulations had to be more pronounced in order to make a discernible difference to observers of the point-light movie clips. Initial visual inspection of the movie clips showed that exaggerating the amplitude of the scores of PC2 (i.e. manipulation >0%) quickly resulted in non-natural-looking walkers compared to diminishing the amplitude by the same percentage. Thus, we scaled the amplitude of the scores of PC2 by −60%, −40%, −20%, 0%, and +20%, thus creating another set of five modified versions of each point-light walker.

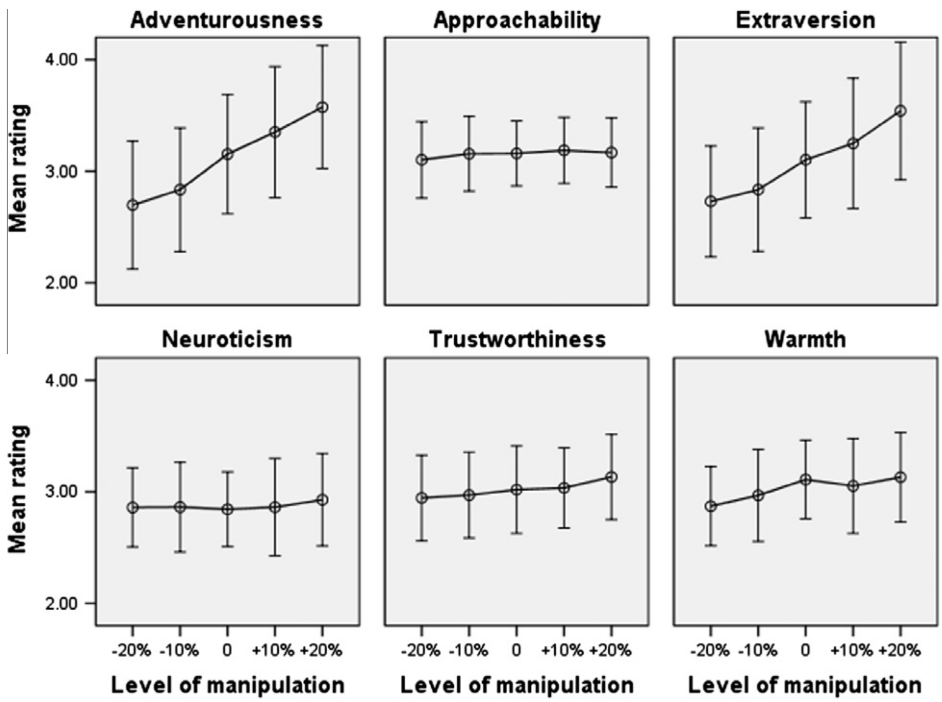

Fig. 2. Mean trait ratings (± 1*SD*) on six scales for five levels of manipulation of amplitude of PC1 scores.

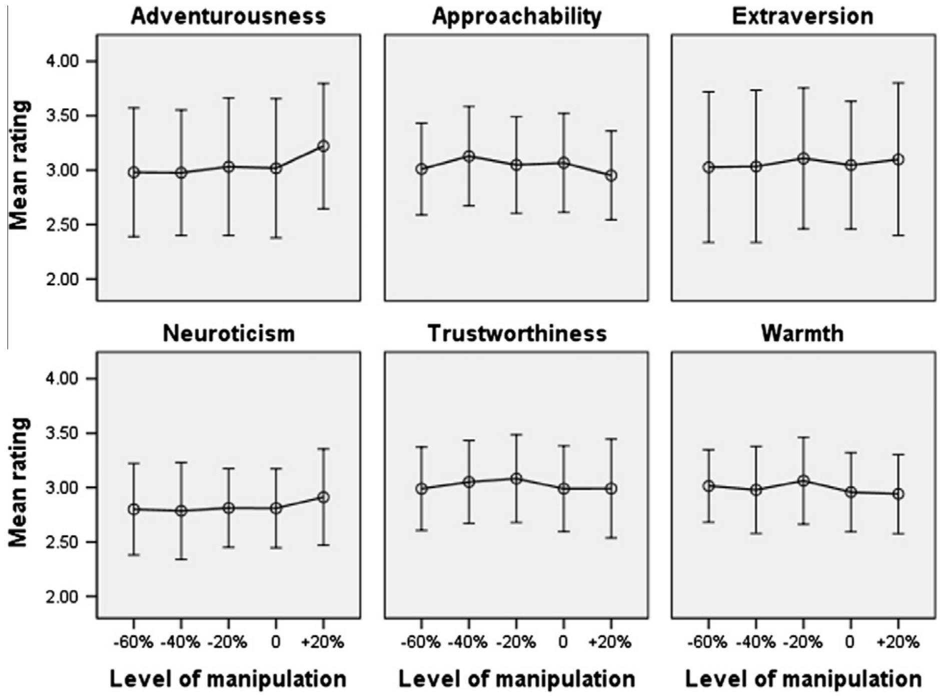

Fig. 3. Mean trait ratings (± 1*SD*) on six scales for five levels of manipulation of amplitude of PC2 scores.

3.2.1. Method

Twenty-one new observers were used (5 male, 16 female), drawn from the same population as Experiment 2A and with similar age demographics ($M = 21.1$, $SD = 2.9$). All further procedures were identical to that of Experiment 2A.

3.2.2. Results and discussion

There was good inter-rater reliability amongst observers on most scales (neuroticism $\alpha = .66$; all other αs > .71), as shown in Supplementary Table S2. The findings show that manipulation of PC2 had an effect on trait ratings, $F(24, 332.6) = 2.09$, $p = .002$, although this effect was small ($\eta_p^2 = .12$). This held for adventurousness alone, $F(4, 100) = 6.45$, $p < .001$, $\eta_p^2 = .21$. As illustrated in Fig. 3, trend analyses show that the only significant linear effect of amplitude manipulation was on adventurousness, $F(1, 25) = 10.49$, $p = .003$, $\eta_p^2 = .30$, with higher amplitudes corresponding to higher trait ratings. This is not in line with findings from Experiment 1, which showed that PC2 correlated with neuroticism only (see Section 2.2.1).

4. Study 3: additional trait ratings of unmodified point-light walkers

The results of Study 1 suggest that the personality traits of the walkers were not the driving factors for trait impressions, directly or indirectly (see Section 2.2.2). This finding was further strengthened by the second analysis (Section 2.2.3), in which we found no relationship between self-reported personality and the motion parameters. In Study 3, we therefore investigated whether alternative underlying factors may be directly or indirectly driving the reliable trait impressions of point-light walkers. To do this we assessed to which degree, if at all, impressions of personality were associated with judgements of age, health, physical attractiveness, masculinity, arousal and valence (henceforth *predictor variables*).

The chosen predictor variables have been shown to be associated with personality and first impressions to some extent. We collected ratings of age because this has been found to be associated with perceived personality in point-light walkers (Montepare & Zebrowitz-McArthur, 1988). Attractiveness has been found to predict personality impressions, such as extraversion ratings based on faces (Albright et al., 1988). Attractiveness is closely linked to perception of health, consistent with the 'good genes' hypothesis, which posits that healthy individuals are attractive because of the importance for mate selection (Jones et al., 2001). It is also worth noting that health ratings based on body motion have been found to predict voting choice (Kramer et al., 2010). We therefore collected data on the perceived health of the walkers. Masculinity ratings were also collected, as personality ratings may be due to different social stereotypes for males and females; for instance, males are typically seen as less neurotic and more extraverted than women (Williams, Satterwhite, & Best, 1999). Finally, we measured perceived arousal and valence to obtain measures of emotion. Indeed, it has been found that people attribute emotion to emotionally neutral faces and this can fuel subsequent trait judgements of said faces (Montepare & Dobish, 2003).

4.1. Method

In Experiment 3A, we collected data on the perceived masculinity of each walker. Observers ($n = 15$; 3 male

Table 4
Correlations (Spearman) between predictor variables and personality trait ratings.

Trait scale	Masc.	Age	Attr.	Heal.	Arou.	Val.
Age	.23					
Attractiveness	−.13	−.83***				
Health	−.33	−.85***	.86***			
Arousal	−.40*	−.67***	.60***	.77***		
Valence	−.16	−.81***	.71***	.80***	.59**	
Adventurousness	−.23	−.70***	.55**	.73***	.74***	.79***
Approachability	.12	−.23	.44*	.16	−.27	.32
Extraversion	.00	−.69***	.57**	.67***	.58**	.82***
Neuroticism	−.57**	−.39	.30	.51**	.76***	.25
Trustworthiness	−.15	−.53**	.60**	.54**	.22	.68***
Warmth	−.13	−.46*	.49*	.38	.14	.68***

Note: Masc = Masculinity.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

and 12 female; Mean age = 19.0, *SD* = 0.9) were shown the stimuli in a random order and asked to indicate which gender they believed the walker to be by using the keyboard, thus using the same procedure as Montepare and Zebrowitz-McArthur (1988). For each stimulus, masculinity was calculated as the proportion of participants who judged a stimulus to be 'male'.

In Experiment 3B, a different group of participants ($n = 21$; 3 male and 18 female; mean age = 19.7, *SD* = 6.0) was asked to estimate the targets' age. Participants first undertook six practice trials in order for them to form an impression of the mean age of the targets. These practice clips had been previously selected to vary in perceived age on the basis of the judgements of four separate observers. The practice stimuli were sampled from the same target walks used in the experimental trials, but different versions of the walks were used during the practice. Following the practice trials, participants were shown all 26 stimuli randomly, and asked to indicate how old they perceived the walker to be. This predictor variable of age was chosen in order to follow the procedures of Montepare and Zebrowitz-McArthur (1988), who found youthfulness to predict personality trait impressions. The mean judged age across all participants was used as our final measurement of youthfulness.

Finally, in Experiment 3C, a third group of participants ($n = 22$; 4 male and 18 female; mean age = 19.7, *SD* = 4.8) rated the target walkers on physical attractiveness, health, arousal and valence on five-point rating scales. The antonyms 'unattractive-attractive', 'unhealthy-healthy', 'calm-excited' and 'unpleasant-pleasant' were used.

All further methods, as well as apparatus, were identical to those employed in Experiment 1.

4.2. Results and discussion

Inter-rater reliability was good for all predictor variables: masculinity ($\alpha = .86$), age ($\alpha = .89$), attractiveness ($\alpha = .86$), health ($\alpha = .94$), arousal ($\alpha = .95$) and valence ($\alpha = .87$).

Accuracy was above chance for judgements of gender of both male (one-sample *t*-test: $t_{10} = 9.15$, $p < .001$) and female ($t_{12} = -3.34$, $p < .01$) walkers. Male walkers were correctly classified in 86.0% of the trials whereas females were correctly classified in 70.4% of the trials. Perceived age of the targets ($M = 35.4$, $SD = 8.5$) varied highly between targets (range: 23.1–56.8) and was significantly higher than their actual age ($M = 19.3$, $SD = 0.9$), $Z = 4.5$, $p < .001$, $r = .87$. The two variables were not correlated: ($\rho = -.01$, $p = .97$).

The two motion parameters that were found to drive personality ratings in Study 1 (i.e., amplitudes of PC1 and PC2) showed a pattern of correlations with the predictor variables. A dissociation was found, whereby PC1 amplitude correlated with attractiveness ($\rho = .46$, $p = .02$), health ($\rho = .48$, $p = .01$), valence ($\rho = .58$, $p < .01$) and perceived age ($\rho = -.40$, $p = .04$), whilst PC2 amplitude correlated with arousal ($\rho = -.53$, $p < .01$) and masculinity ($\rho = .62$, $p < .001$). Strong correlations were also seen with the previously collected trait ratings. For instance, extraversion correlated with all scales (all absolute $\rho s > .57$, all $ps < .003$) apart from masculinity ($\rho = .00$, $p = .98$). See Table 4.

Stepwise regression analyses were carried out for each personality trait individually (see Table 5). The results revealed that the variables chosen to obtain an estimate of perceived emotion (i.e. arousal and valence) were retained as predictors of all personality traits. For instance, valence was retained as a predictor in all personality trait ratings apart from approachability. High arousal was associated with perceived adventurousness and neuroticism, whilst low arousal was associated with perceived approachability and warmth. Two other rating variables unrelated to emotion were also kept: masculinity predicted emotional stability, and attractiveness predicted approachability. The final two predictor variables, age and health, were not retained by any of the regression analyses.

It thus appears that personality ratings may have been mediated by impressions of emotion, reflected in the number of stepwise regression analyses that kept the predictors arousal and valence (either alone or combined). Judgements of masculinity and attractiveness were found to predict emotional stability and approachability (respectively). We note that a high degree of colinearity was found, with

Table 5
Stepwise regression analyses with predictor variables and personality trait ratings.

Trait scale	Predictor variable				R^2
	Arousal	Valence	Masculinity	Attractiveness	
Adventurousness	0.50 (4.23***)	0.50 (4.22***)	–	–	0.84
Approachability	−0.81 (5.85***)	–	–	1.06 (7.65***)	0.73
Extraversion	–	0.79 (6.33***)	–	–	0.61
Neuroticism	0.89 (4.97***)	−0.49 (2.99**)	−0.31 (2.39***)	–	0.70
Trustworthiness	–	0.76 (5.65***)	–	–	0.57
Warmth	−0.38 (2.13*)	1.00 (5.58***)	–	–	0.62

Note: Numbers represent Standardised β-coefficients (*t*-tests in brackets) for six separate stepwise regression analyses. Six predictor variables were entered into the stepwise regression (age and health were not retained by any of the analyses). R^2 = goodness of fit for the given model.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

many of the predictor variables strongly correlated; for instance, as can be seen in Table 4, attractiveness and health showed a correlation coefficient of .86 ($p < .001$). This multicolinearity—which must be expected for rating scale variables of this type—means generalisations drawn from the regression analyses should be treated with caution. However, overall, the outcome from the multiple regressions is consistent with previous research on person perception (Montepare & Dobish, 2003) and fits with empirical evidence that perception of emotion can affect personality attribution (Montepare & Dobish, 2003).

5. General discussion

The overall aim of the studies reported here was to assess the link between bodily motion and personality, with special emphasis on perceived traits. In Study 1, we showed that point-light walker stimuli depicting single gait cycles were reliably rated on six personality traits. This finding adds to a range of studies showing consensus at zero acquaintance (Albright et al., 1988, 1997; Ambady & Rosenthal, 1993; Engell et al., 2007; Heberlein et al., 2004; Kenny et al., 1994).

Our motion data were reduced using PCA (Troje, 2002), and three principal components explained on average 98.7% of the variance. These PCs were summarised by sinusoidal parameters that were unrelated to the actual personality traits of the target individuals, as measured through a self-reported personality questionnaire (Costa & McCrae, 1992). However, the amplitudes of the sinusoidal functions describing the first and second PCs were related to *perceived* personality.

Results from Study 2 partially confirmed the link between motion parameters and perceived personality. Two experiments were carried out in which PC1 and PC2 were separately manipulated. The systematic manipulation of the amplitude of the first component (PC1) had an impact on trait ratings, in line with the findings from Study 1. The impact of manipulation of PC2 was weak and, contrary to the manipulation of PC1, did not corroborate the findings from Study 1. It could be that the higher magnitude of manipulations required for PC2 made the walkers less natural-looking. This may not be surprising given that the second principal component, on average, accounted for 6.6% of the variance of the motion data. Our study did not simultaneously manipulate PC1 and PC2. Although it is possible that personality impressions depend on interactions of these two parameters, the weak correlation coefficients from Study 1 made us abandon such an elaborate design. However, future studies, with different stimuli, may allow investigating whether such interactions are possible.

Self-reported personality was not predictive of personality trait attribution. In Study 3, we therefore investigated whether personality trait impressions may rely on other judgements. Our analyses indicated that perception of emotion, masculinity and attractiveness may be mediating factors for personality trait attribution.

The lack of a relationship between observer ratings and self-reported personality scores contrasts with studies reporting a Kernel of Truth in ratings of personality traits (Borkenau et al., 2004; Penton-Voak et al., 2006). Accurate and early decisions of traits such as neuroticism can be considered advantageous since prediction of immediate behaviour carries an adaptive advantage (Barrett et al., 2005). We acknowledge that our limited sample size may not have given this particular analysis in our study enough power. However, most previous studies reporting a Kernel of Truth when a confederate makes personality judgements of a stranger have allowed for different cues to be available to the confederate, such as the face (Penton-Voak et al., 2006) or even verbal information (Borkenau et al., 2004). Indeed, Montepare and Zebrowitz-McArthur (1988) did not find support for a kernel of truth when assessing perceived personality of point-light walkers; likewise, Kenny, Horner, Kashy, and Chu (1992) found no validity in trait judgements when observers were shown 20-s silent video tapes of targets who were seated and unaware of being recorded.

Moreover, empirical evidence that perceived emotion influences personality trait attribution (e.g., Montepare & Dobish, 2003) indicates that people are not infallible in their judgements, since emotions are not stable traits. This is indeed plausible in our point-light stimuli, as supported by the finding that ratings of arousal and valence were strongly linked with our observers' personality trait impressions.

Bringing together the results from the Effort-Shape analyses, the PCA and the multiple regression analyses, we found that PC1 amplitude, which appeared to be linked with high use of personal space, may have driven personality trait ratings through impressions of valence. High PC1 amplitudes resulted in stimuli being perceived as more positive. The motion parameter PC2 amplitude, which was tied with the impression of a relaxed, yet focused walk, had a negative impact on arousal, with high amplitude resulting in stimuli being perceived as calmer.

In summary, we have shown that observers reliably form first impressions from an individual's gait even when the dynamic stimuli have highly degraded static form information, as is the case with our point-light walkers. Although observers' trait ratings did not accurately reflect the self-rated personality traits of the walkers, we stress that this lack of validity in the trait judgements does not remove the practical implications of our findings. In particular, the results from Study 2 may be of relevance to creation of computer avatars used for entertainment or marketing. These results may also be of relevance for human interactions, since first impressions are automatic (Asch, 1946; Willis & Todorov, 2006) and can affect social decisions (Little et al., 2007; Todorov et al., 2005). However, it is not certain that minimal cues identified here can be 'taught' or that such instructions may be effective. Further studies will be required to verify this. We also do not know whether people use bodily motion as cues for personality when information such as facial expressions, clothing or verbal behaviour is available to the observer. However, based on previous studies showing that important social decisions can be traced down to movement cues (Kramer et al., 2010) we believe that this may be the case.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2012.05.018.

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