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Perceiving personality in simple motion cues

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ABSTRACT

People often ascribe intentions and personalities to simple motion cues. Two experiments were conducted to examine how variations in motion quality, such as amplitude and frequency, influence a simple stimulus' ratings on different aspects of personality. In experiment one participants were asked to adjust the motion behavior of a computer animated ball according to different items, which were based on the five factor model of personality. In experiment two participants had to assign the 'correct' personality to stimuli that were based on data of experiment one. Recognition rate was high for most personality traits, but there were also some misidentifications. Results suggest that simple features of motion partly influence social perception and human communication.

1. Introduction

Human communication is more than the exchange of verbal messages. People judge others by their appearance and ascribe social meaning to subtle cues. Even simplified and abstract stimuli such as triangles or circles moving around on a screen are often interpreted as humans or animals interacting in a purposeful manner. Michotte (1963), for instance, investigated how simple stimuli affect impressions of causality. By building an apparatus that created the illusion of two rectangles colliding he was able to establish some "rules" for people's attributions of cause and effect. Among other factors the interpretation of such events was influenced by variations in relative and absolute speed of the objects, differences in the duration and the angles of their trajectories and spatial and temporal gaps. Although Michotte's methodology had its flaws, studies using more sophisticated animations found that observers agree above chance level in their interpretation of such and similar stimuli. Thus, the functional relations Michotte established have been replicated and extended (Morris & Peng, 1994; Scholl & Nakayama, 2002; Scholl & Tremoulet, 2000; White, 2006).

Another line of research has demonstrated that people perceive animations of featureless geometric figures as human or animal social behavior (Heider & Simmel, 1944). Observers ascribe intentions, personalities and emotions to the moving figures. Such attributions have been shown to be consistent across many cultures and there is evidence that even infants interpret simple motion sequences as goal driven behavior (Csibra, Gergley, Bíró, Koós, & Brockbank, 1999; Gergely, Nádasdy, Csibra, & Bíró, 1995; Scholl & Tremoulet, 2000). Furthermore, groups of moving objects create similar impressions as a single object performing the same movements. Thus, if people perceive a moving stimulus as an entity of its own it is the motion kinematics and not the outward features of the objects that are responsible for the attributions made (Bloom & Veres, 1999).

Analysis and simulation of natural behavior also reveals that motion cues guide human perception and communication. People, for example, are able to recognize a human body in movies displaying a person's behavior as a changing pattern of dots (Johansson, 1973). This methodical approach of attaching reflective markers to the major joints of a person has triggered a great deal of additional investigations showing that these so called 'point light' displays convey information about age, gender, animacy and emotional states (Blake & Shiffrar, 2007; Chang & Troje, 2008; Dittrich, Troscianko, Lea, & Morgan, 1996; Kozlowski & Cutting, 1977; Pollick, Patterson, Bruderlin, & Sanford, 2001; Troje, 2002). Research based on such an optical motion capture system even found movement patterns of dancers to covary with their personality and the music heard during the dance (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010).

An alternative way of analysis makes use of the fact that changes in pixel color are in accordance with the movements of a filmed person. Applying this method it was revealed that different motion qualities (i.e. kinematics) are related to dancers' ratings of attractiveness and their personality (Bechinie & Grammer, 2003; Grammer, Honda, Juette, & Schmitt, 1999). Further, research analyzing ratings of stick figure movies that were based on politicians making a speech found significant correlations between certain motion qualities and different personality traits (Koppensteiner & Grammer, 2010). In conclusion, all these results suggest that a wide range of social information is communicated by formless features of motion.

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According to Oberzaucher and Grammer (2008) human communication works on different levels ranging from symbolic information conveyed by verbal content to information that has no definite signal character and is expressed by certain qualities of motion. Thus, speed, duration and flow of a gesture can change its meaning considerably. In our study on politicians in which we used stick figures as stimuli, we were able to establish a relationship between extraversion and the amount of activity. Furthermore, there was a correlation between high emotional stability and movements with smooth transitions from one peak of activity to the next, and a correlation between openness and the direction of motion (Koppensteiner & Grammer, 2010). Consequently, people ascribed personalities to changes in amplitude height and velocity, which are qualities that are not tied to the activity of a particular set of body parts. This raises the question if people are still able to make such attributions when presented with motion patterns that have nothing in common with a human body. In other words, is it possible to process social information on a very abstract level and do people ascribe different personality traits to the motion patterns of a simple cue?

In order to find an answer to these questions I devised a methodology that resembled a Brunswik (1956) lens model analysis (e.g. Borkenau & Liebler, 1992; Gifford, 1994; Gosling, Ko, Mannarelli, & Morris, 2002). Although I did not compare self-reports with observer ratings as intended by the original framework of this model, my research was also divided into a phase of behavior encoding and a subsequent phase of behavior decoding. The stimulus I used was a computer animated ball, whose trajectory was based on simple sine waves. This is an easy way of displaying variations in amplitude and speed on an abstract level, because periodic changes in both parameters can be modified on a linear scale. In addition, similar to the voice signal that is comprised of different frequencies it is possible to sum up sine waves of different periodic length in order to produce more complex motion patterns. The current study was a first step only, but presents a framework that could be extended to produce prototypical motion patterns in a highly controllable manner, thereby supporting research that has isolated such motion patterns in natural human behavior.

2. Method

2.1. Participants

Two rating experiments were conducted at the University of Vienna (faculty of life sciences). For each experiment a separate group of student volunteers were recruited. Thirty-four (16 female and 18 male) participated in experiment one ($M = 22.35$ years of age; $SD = 3.58$) and 39 (23 female and 16 male) participated in experiment two ($M = 24.08$ years of age; $SD = 34.86$). The participants were naive to the purpose of the study and did not receive a financial reward.

2.2. Stimuli

The stimuli for both rating experiments were presented on a computer screen using a program that had been developed especially for the purposes of this study. The program consisted of an animation window, in which the stimuli were displayed, and a second window that resembled a control panel. In experiment one this control panel contained four so called slider controls, which enabled the raters to change the motion behavior of the stimuli by manipulating the slider's bar with the computer mouse (see screen capture in online version of the paper). In experiment two the control panel contained ten sliders, which the raters used to judge the personality of the presented stimuli.

The stimulus was a black circle moving from the left to the right, reemerging on the left border when touching the right border of the window. The background of the window was white. The vertical movements of the circle (i.e. movements along the *Y*-axis) were based on a sine wave and the horizontal movements were created by adding a linear vector to the *X*-coordinate of the stimulus. This means that the circle moved along and oscillated around an invisible horizontal line.

In experiment one the participants manipulated the behavior of the black circle by using the sliders of the control panel. The first slider changed the amplitude of the sine wave, making the oscillations of the circle higher or lower. The second slider changed the period length of the sine wave, making the circle oscillating faster or slower. The third slider had an effect on the horizontal movements, manipulating the circle's velocity when moving from the left to the right. The last slider changed the period length and the amplitude of an additional sine wave that oscillated with half of the amplitude and three times faster than the basic wave. Therefore, this slider added a more or less pronounced trembling to the circle's motion behavior. All sliders were equipped with a bar that could be moved horizontally with a computer mouse. The position of the bar was equal to values ranging from one to the maximum value of ten. Thus, the circles behavior could be manipulated choosing one of nine different positions of the slider's bar for each of the four sliders. High values of the corresponding slider bar were equivalent to high amplitude, high frequency, high horizontal velocity and more trembling.

2.3. Procedure

For both rating experiments potential participants were approached at the University and asked if they want to take part in a short experiment. The participants were brought into a separate room with several computers and received instructions on how to use the rating program. In experiment one the participants were asked to change the trajectory of the stimulus according to 20 personality items of a brief German version of the NEO-FFI (Borkenau & Ostendorf, 1991). Four items, representing low or high values of one of the Big Five personality traits (e.g. low extraversion, high extraversion, low openness, high openness, etc.) were displayed in random order in the upper left corner of the animation window. This means that the participants had to use the slider controls to change the black circle's movements according to ten different quartets of personality items. The participants had no time limit; they switched from one group of items to the next by clicking on a button in the control panel window.

By averaging the slider values for each item group of experiment one I prepared a kind of 'prototype' stimuli for a second rating experiment. Thus, the participants of experiment one helped to create the stimuli for a separate group of participants in experiment two. Ratings were done on ten sliders which were named after the ten different item groups of the first experiment. Consequently, each participant of the second experiment rated ten different 'prototype' motion cues (i.e. randomly ordered stimuli representing low extraversion, high extraversion, low agreeableness, high agreeableness, etc.) on ten corresponding personality scales. The position of the slider bars was equivalent to values ranging from one to ten with one expressing low agreement and ten expressing high agreement.

3. Results

3.1. Study 1

In experiment one each participant changed a black circle's movements to represent ten different groups of personality items in the most appropriate way possible. To prepare a kind of 'prototype' stimuli for experiment two, these ratings (i.e. positions of slider bars) were averaged for each group of personality items (see Table 1). The presented results are descriptive, but they give an overview of how the participants adjusted the stimuli's motion behavior to information about personality. Although different combinations of the four slider values produced different behaviors, the results indicate that some motion qualities were predominantly associated with certain personality traits. High values on the motion quality 'trembling', for instance, were primarily selected for personality items representing low emotional stability, low agreeableness and low conscientiousness. The values of 'horizontal velocity', on the other hand, were very equally distributed across the different traits, indicating that this motion quality might have limited signal value. Further, most personality traits attained relatively high values in 'amplitude', whereas there were a bit more pronounced differences regarding the 'frequency' of the stimuli's movements.

In order to examine these patterns in more detail I performed a discriminant analysis using the opposite pairs of the personality traits as dichotomous criterion and the four slider values as independent variables. This procedure yielded significant differences between low and high emotional stability (Wilks Lambda = .16; $\chi^2(4) = 115.93$; $p = .000$), between low and high agreeableness (Wilks Lambda = .45; $\chi^2(4) = 50.73$; $p = .000$), between low and high extraversion (Wilks Lambda = .33; $\chi^2(4) = 70.75$; $p = .000$), between low and high conscientiousness (Wilks Lambda = .28; $\chi^2(4) = 82.61$; $p = .000$) and between low and high openness (Wilks Lambda = .56; $\chi^2(4) = 37.47$; $p = .000$). Univariate analysis of variance (see *F*-tests in Table 2) and the structure matrix of the discriminant analysis (i.e. correlation coefficients of each independent variable with discriminate function) helped to explain to what extent the different motion qualities differentiate between the opposites of the personality traits (Table 2).

Analysis of low and high emotional stability, for instance, yielded a high loading for the variable 'trembling' ($r = .92$), a highly significant difference for this motion quality, and a significant difference for 'frequency'. These results and the means of the slider values show that low emotional stability was associated with a 'trembling' ball that displays fast changes in amplitude height. A ball with smooth movements (i.e. no trembling and low frequency), on the other hand, was related to high emotional stability.

Similar results were found for agreeableness and conscientiousness. These personality traits were also related to the variables 'trembling' and 'frequency', but in contrast to emotional stability and conscientiousness agreeableness attained a relatively high loading on 'frequency' ($r = .40$). This and the slider means indicated that high agreeableness was preferably related to slowly changing amplitude heights and low values for 'trembling'. Quite the opposite was true for low agreeableness. Although similar patterns were found for conscientiousness, there was also a difference.

Table 2
Discriminant analysis.

	Motion parameters			
	Frequency	Hori. velocity	Amplitude	Trembling
Low and Hi Emot. Stab.				
F	12.5***	.8	1.1	286.1***
Structure matrix	.19	−.05	−.06	.92
Low and Hi agreeableness				
F	12.4***	.08	.5	75.99***
Structure matrix	.40	−.03	−.08	.98
Low and Hi extraversion				
F	55.99***	55.61***	70.00***	8.43***
Structure matrix	.72	.65	.65	.25
Low and Hi openness				
F	.13	.10	50.62***	.77
Structure matrix	−.05	.04	.98	−.12
Low and Hi cons.				
F	10.53***	5.38**	1.65	151.14***
Structure matrix	.25	.18	.10	.93

Note. Four items formed a personality trait; the higher a value the higher the corresponding motion quality; emot. stab. = emotional stability; agreebl. = agreeableness; cons. = conscientiousness; hori. = horizontal; Hi = high; trembling was a fast oscillating sine wave added to the basic wave; *df1* = 1; *df2* = 66 for *F*-tests.
** $p < .01$.
*** $p < .001$.

The variable 'horizontal velocity', which seemed to play no role for emotional stability and agreeableness, yielded a significant result for this personality trait. Therefore, low and high conscientiousness could be separated by opposite slider positions of 'frequency', 'trembling', and 'horizontal velocity'.

Extraversion yielded significant differences for all of the four motion qualities. Further, high positive loadings were obtained for frequency, horizontal velocity and amplitude. On comparison, the variable 'trembling' was of minor importance. It seemed that low extraversion was expressed by the absence of activity, whereas high extraversion was expressed by a controlled way (i.e. low 'trembling') of high activity.

Openness yielded a significant result for the motion quality 'amplitude'. This variable was also the only one to achieve a high loading ($r = .98$). Therefore, high openness was related to oscillations with high amplitude, and low openness was related to oscillations with low amplitude.

3.2. Study 2

In experiment two participants were asked to identify the stimuli that had been created by the participants of experiment one. Strictly speaking, data from experiment one was used to produce ten 'prototypical' motion behaviors representing low and high values of the Big Five personality traits (e.g. low extraversion

Table 1
Descriptive statistics of motion parameters.

Personality	Frequency	Hori. velocity	Amplitude	Trembling
Low emot. stab. *M* (*SD*)	4.4(3.5)	2.9(2.5)	4.0(3.5)	7.9(2.3)
High emot. stab. *M* (*SD*)	2.1(1.4)	3.4(2.3)	4.9(3.2)	1.1(.3)
Low agreebl. *M* (*SD*)	6.3(3.6)	4.0(3.2)	5.9(3.5)	6.5(2.9)
High agreebl. *M* (*SD*)	3.7(2.2)	3.9(1.7)	6.4(2.9)	1.7(1.3)
Low conscient. *M* (*SD*)	4.7(3.3)	4.7(2.7)	6.4(3.4)	7.6(2.8)
High conscient. *M* (*SD*)	2.6(2.2)	3.4(1.9)	5.3(3.4)	1.3(1.1)
Low extraversion *M* (*SD*)	1.8(1.3)	1.7(1.1)	2.2(2.0)	1.4(.8)
High extraversion *M* (*SD*)	5.6(2.7)	5.2(2.6)	7.0(2.7)	2.7(2.5)
Low openness *M* (*SD*)	3.9(3.3)	4.1(3.0)	2.7(2.4)	3.4(3.4)
High openness *M* (*SD*)	3.6(2.0)	4.3(2.4)	7.0(2.5)	2.7(2.3)

Note. Four items formed a personality trait; the higher a value the higher the corresponding motion quality; emot. stab. = emotional stability; agreebl. = agreeableness; conscient. = conscientiousness; hori. = horizontal; trembling was a fast oscillating sine wave added to the basic wave; $n = 34$.

Table 3
Test for concordance of "prototype" motion stimuli (Kendall W).

Stim	Average rankings										W
	Lo E	Hi E	Lo A	Hi A	Lo C	Hi C	Lo Ex	Hi Ex	Lo O	Hi O	
Lo E	8.62	3.26	6.04	4.63	8.27	3.94	4.74	5.28	5.13	5.10	.39**
Hi E	4.06	7.85	4.01	6.40	4.01	7.32	7.31	4.88	4.42	4.73	.30**
Lo A	7.62	4.12	5.18	5.53	7.38	4.13	4.72	6.23	5.27	4.83	.20**
Hi A	3.58	8.55	3.19	7.78	3.81	6.88	4.82	6.83	3.63	5.92	.48**
Lo C	8.31	3.19	6.13	4.72	7.94	3.79	4.60	5.91	4.83	5.58	.35**
Hi C	4.05	8.62	3.28	7.32	3.42	7.76	5.35	5.62	3.96	5.63	.44**
Hi Ex	5.00	6.60	4.15	6.92	4.83	5.78	3.49	7.31	4.17	6.74	.23**
Lo Ex	4.81	7.62	4.67	5.63	3.83	7.22	8.55	3.38	4.97	4.32	.39**
Lo O	4.46	7.53	3.77	6.40	3.60	7.47	7.56	4.59	4.73	4.88	.32**
Hi O	4.27	7.17	3.77	7.44	4.72	6.40	3.42	7.83	3.85	6.14	.36**

Note.; rows = personality ratings' average rankings; Lo = low; Hi = high; E = emotional stability; A = agreeableness; C = conscientiousness; Ex = extraversion; O. = openness; Stim = stimulus type; $n = 39$ (for each stimulus type).
** $p < .01$.

stimulus, high extraversion stimulus, low agreeableness stimulus, etc.) and each of these 'prototypes' was rated on ten corresponding scales (e.g. scale for low extraversion, scale for high extraversion, scale for low agreeableness, etc.). In order to assess the raters' agreement with regard to the ten scales I applied the Kendall W statistic that ranges from 0 (no agreement) to 1 (total agreement). Table 3 reports the results of this procedure and presents an overview of the ratings' average rankings (i.e. give an estimate of how often a 'prototype' stimulus was rated highest on one of the scales, how often it was rated second highest, etc.) for each 'prototype' stimulus. For instance, motion behavior representing low emotional stability was preferably rated highest on the low emotional stability scale (average ranking = 8.62) and lowest on the high emotional stability scale (average ranking = 3.26).

Measurements of concordance concerning the ratings of the participants were significant in all of the cases, but on average only moderate levels of agreement were achieved (W's ranging from .20 to .48). Further, 'prototype' stimuli displaying different 'manifestations' of the personality traits were not always ranked highest on the corresponding rating scales. For instance, 'prototypes' representing high agreeableness and high conscientiousness achieved the highest average ranking on the scale for high emotional stability. Moreover, stimuli of these categories were rated nearly equally high on the scales for high agreeableness, high emotional stability and high conscientiousness. Similar relations were obtained for the opposites of these motion stimuli (i.e. low agreeableness, low emotional stability and low conscientiousness 'prototypes'). They were rated high on scales for low agreeableness, low emotional stability and low conscientiousness, thereby revealing a relationship between these kinds of 'prototypical' motion patterns.

Further analysis focused on the differences between personality ratings of 'prototype' opposite pairs. In order to reduce the number of statistical tests and to simplify the interpretation of the results I merged opposing personality ratings of each 'prototype' stimulus into new variables by subtracting them from each other (e.g. ratings on high extraversion scale – ratings on low extraversion scale). This procedure converted the ten original scales into five bipolar scales. High values of a particular personality rating could be expressed then by numbers close to the upper end (e.g. high extraversion) and corresponding low personality ratings by numbers close to the lower end (e.g. low extraversion) of such a bipolar scale.

Based on these combined ratings I examined the differences between the opposites of the 'prototype' stimuli. In other words, bipolar personality ratings ($n = 39$ for each rating scale) of 'prototype' motion patterns representing a personality dimension were compared with bipolar ratings ($n = 39$ for each rating scale) of 'prototype' motion patterns representing the counterpart of this particular personality dimension (e.g. ratings on all five bipolar scales for high extraversion stimulus versus corresponding ratings on all five bipolar scales for low extraversion stimulus). Table 4 reports the descriptive statistics of these analyzes and presents the found differences as point biserial correlations, thereby giving an estimate of effect size (significance testing by t-value). For instance, motion patterns representing low and high emotional stability yielded a high correlation coefficient on scales measuring emotional stability. This indicates that the participants could reliably differentiate between these stimuli. However, analysis revealed that 'prototypes' animations that had been encoded to display emotional stability were rated similarly on bipolar scales for conscientiousness and agreeableness. Such patterns were also found for 'prototypes' of conscientiousness and agreeableness. In all of these cases correlation coefficients were highest for ratings of emotional stability, followed closely by ratings of conscientiousness and ratings of agreeableness on the third position. With a few exceptions the group means replicated this pattern.

'Prototypes' for low and high extraversion, on the other hand, were assigned to the correct category more frequently. Although the rate of misidentifications for this category was relatively low, stimuli displaying high extraversion seemed to be confused with stimuli displaying high agreeableness to a certain extent. Furthermore, ratings for extraversion were related to openness. This was particularly clear for 'prototype' animations of openness. In comparison with the results for extraversion these stimuli only yielded a relatively small effect size in their own category.

4. Discussion

4.1. Present results

Social judgments are not only influenced by smiles and gestures. People also perceive intentionality and different personalities in the behavior of abstract motion cues and they ascribe social meaning to the kinematics of body movements. Building on such findings this study was aimed to examine the relationship between some motion parameters and information about personality. The study was divided into two steps. In experiment one participants were asked to match the behavior of an animated ball to sets of adjectives, which were based on the five factor model of personality. In a second experiment these animations were judged on the same sets of personality items, in order to ascertain whether the participants were able to identify the personality of the stimuli.

During the encoding procedure the behavior of an animated ball was modified according to four motion parameters. This raises the

Table 4
Differences in personality ratings between 'prototype' motion stimuli.

Stimulus	Ratings				
	E	Ex	A	C	O
Hi E/*M*(*SD*)	4.5(4.8)	−2.5(4.1)	2.6(3.9)	3.8(4.5)	.7(3.8)
Lo E/*M*(*SD*)	−5.9(3.1)	.1(3.9)	−1.6(4.1)	−5.0(3.8)	−.6(3.1)
*r*pb	.80**	−.32**	.46**	.73**	.19
Hi Ex/*M*(*SD*)	2.1(4.6)	3.3(3.3)	2.9(4.0)	1.6(4.2)	2.2(3.8)
Lo Ex/*M*(*SD*)	3.1(5.9)	−6.4(2.9)	1.0(4.3)	4.2(3.7)	−1.0(3.8)
*r*pb	−.10	.84**	.23*	−.32**	.40**
Hi A/*M*(*SD*)	5.3(3.3)	2.2(4.5)	4.6(3.0)	3.3(4.1)	2.4(3.6)
Lo A/*M*(*SD*)	−3.1(5.1)	1.0(4.8)	.7(4.0)	−3.4(4.1)	−.3(4.2)
*r*pb	.70**	.13	.49**	.64**	.33**
Hi C/*M*(*SD*)	5.4(3.3)	.4(4.9)	4.2(3.6)	4.6(3.7)	1.6(3.7)
Lo C/*M*(*SD*)	−4.8(3.2)	.7(4.5)	−1.4(4.0)	−4.5(3.8)	.3(4.1)
*r*pb	.85**	−.04	.60**	.78**	.17
Hi O/*M*(*SD*)	2.7(4.1)	3.8(3.5)	3.6(4.0)	1.6(4.0)	2.0(3.2)
Lo O/*M*(*SD*)	3.4(5.4)	−3.4(4.7)	2.7(4.4)	4.0(3.7)	.5 (3.7)
*r*pb	−.07	.66**	.12	−.30**	.22*

Note. Hi = high; Lo = low; E = emotional stability; Ex = extraversion; A = agreeableness; C = conscientiousness; O = openness; rpb = point biserial correlation; *df1* = 1; *n* = 78 (2 × 39 ratings for each test of significance).
* $p < .05$.
** $p < .01$.

question to what extent the participants associated different motion patterns with the selected personality items. Overall, there were significant differences between low and high values of all of the personality dimensions, but discriminant analysis gave a more detailed insight into people's manipulations of the stimuli.

It was revealed, for instance, that participants preferred to equip stimuli expressing high emotionality stability with small values on the variables 'trembling' and 'frequency'. Quite the opposite was found for stimuli expressing low emotional stability. This seemed in accordance with the findings of our study on motion patterns during a speech, because speakers who were perceived as being emotionally stable showed smooth movements with low velocity, whereas speakers who were rated low on emotional stability performed jerky movements with high velocity (Koppensteiner & Grammer, 2010).

Similar results were obtained for agreeableness and conscientiousness. These personality traits were also related to 'frequency' and 'trembling'. On closer examination, however, some differences became evident. In contrast to stimuli that were created to express emotional stability and conscientiousness the variable 'frequency' played a more dominant role for agreeableness. For conscientiousness, on the other hand, the motion parameter 'horizontal velocity' seemed to be an additional explanatory variable.

In experiment two 'prototype' stimuli representing emotional stability, conscientiousness, and agreeableness were recognized quite reliably, but they were also rated similarly in all three categories. Although these stimuli presented different motion patterns the participants could not discriminate between them accurately enough. The differences that had been revealed by statistical analysis are either too subtle or do not constitute signals of their own to prevent such misidentifications. This leads to the conclusion that with regard to these personality traits the participants' impressions were guided by the most prominent motion parameters such as 'frequency' and 'trembling'.

In contrast, results for extraversion provided more clarity. The participants reached a relatively high agreement in identifying this personality dimension. For two reasons this could be expected. First, the encoding procedure produced 'prototype' stimuli for this personality dimension that were characterized by pronounced differences in all of the four motion parameters. In comparison with the motion patterns created for rest of the stimuli this was 'unique'. Second, in studies on person perception and 'thin slices' of behavior it is a common finding that extraversion is an easy trait to recognize (Hall, Andrzejewski, Murphy, Mast, & Feinstein, 2008; Kenny, Horner, Kashy, & Chu, 1992). Furthermore, results of our study on motion patterns of politicians suggested that high extraversion is predominantly attributed to high activity. The opposite was true for low extraversion. A similar interpretation can be applied to the findings of this study. The 'low extraversion' stimulus was equipped with low values on all of the four motion parameter, as opposed to the 'high extraversion' stimulus, which was significantly different from that in each of these aspects. It seemed, therefore, that the participants of this study also related high and low values of extraversion to high and low activity.

4.2. Limitations and future directions

The Big Five Personality dimensions have been constructed as statistically independent categories that could be isolated in different human languages (McCrae & Costa, 1997). In this study I was unable to establish such independent categories. Analysis failed to provide motion patterns that could be assigned exclusively to one of the personality dimensions. This might be due to the type of stimuli I used, but it is also not unusual to find certain nonverbal signals to be associated with several personality traits. Research on person perception, for example, has shown that nonverbal cues such as smiles and gestures are often perceived as expressing different attributes of personality (e.g. Gifford, 1994; Naumann, Vazire, Rentfrow, & Gosling, 2009). This was also supported by our study on the body motion of politicians. We found head movements to be correlated with emotional stability, conscientiousness and openness (Koppensteiner & Grammer, 2010).

Although the Big Five personality dimensions have been conceived as independent factors, some investigations were able to establish a higher-order two factor solution (DeYoung, 2006; DeYoung, Peterson, & Higgins, 2002; Digman, 1997). The first factor, labeled as alpha (Digman, 1997) or stability (DeYoung, 2006), encompasses the dimensions of agreeableness, conscientiousness and emotional stability, whereas the second factor, which was labeled as beta or plasticity, subsumes the domains of extraversion and openness. DeYoung (2006) interprets common variance of agreeableness, conscientiousness and emotional stability as an individual's tendency to maintain stability and avoid disruption in emotional, motivational and social domains. Common variance of extraversion and openness, on the other hand, is regarded as a tendency to explore and to deal flexibly with novelty. Both factors are assumed to be related to human basic concerns.

Results of the experiments done here support the existence of the metatraits described above by finding ratings for emotional stability, conscientiousness and agreeableness to be interconnected and a less pronounced but noteworthy relationship between extraversion and openness. It is, therefore, conceivable that higher-order personality factors play a role in human communication. Whether a person is high or low on the factor stability and how he or she reacts to novelty (i.e. plasticity) might be of great importance during a first encounter and enable the communication partners to determine which path an interaction takes. Thus, first impressions might be based on broad categories of personality traits, which are inferred from nonverbal features such as those described here. Only after that a more refined analysis of character traits might follow. These considerations are of course speculative and require empirical support from further studies on abstract motion cues, but also from studies done in natural environments.

Research applying a Brunswik lens model (1956) provided evidence that people were able to accurately judge some personality traits of strangers, but there was no perfect match between nonverbal cues and self-ratings and nonverbal cues and observer ratings (Borkenau & Liebler, 1992; Gifford, 1994; Naumann et al., 2008). It seems a common pattern that observers value the importance of some cues very high. In this study something similar might have happened. Although analysis revealed that the stimuli created in the first experiment were composed of different patterns, participants of the second experiment based their judgments on the most conspicuous features of the stimuli's behavior.

Some of the difficulties to classify the animations correctly might be due to the choice of parameters that were manipulated during the stimulus creation phase. It was the aim of this study to produce a relatively high amount of variations by modifying a relatively small number of parameters. The range of variations, however, was limited. This might have caused the problems that arose during analysis, but also kept the encoding procedure simple. Different motion behaviors could be described by the combination of only four different values. Nevertheless, future research will have to extend the methodology applied here to create more complex motion cues. An increase in complexity, however, can only be achieved by a stepwise approach, because participants would experience difficulties to encode the behavior of a stimulus that is composed of too many variables.

Previous studies on body movements found significant correlations between different motion qualities and impression formation (Grammer et al., 1999; Koppensteiner & Grammer, 2010; Pollick et al., 2001). Although natural behavior often produces complex patterns with sudden and unpredictable changes, these findings suggest that the relationship between observer ratings and some features of body motion can be described by a linear model. Consequently, it appeared conceivable that an abstract motion cue, whose behavior could be modified according to linear scales, would also convey social meaning. The parameters of a sine function can be manipulated on such a linear scale, thereby producing changes in amplitude and frequency. In addition, it is possible to combine sine waves of different periodic length to produce oscillations of higher complexity. For these reasons the animations that were used for the experiments done here were based on two different sine waves. This allowed variations that are similar to the motion cues that have been extracted from natural behavior. Such a stimulus, however, follows a periodic pattern and does not display any of the irregularities that natural behavior also contains. For instance, one might speculate that non-rhythmic or erratic variations might help to find 'prototype' stimuli that produce categories with a minor degree of overlaps. It was already mentioned before that it requires more than one study to produce stimuli of higher complexity, but the work done here provides a sound basis to start from.

Very simple displays so called low level percepts can lead to high level interpretations of causality and animacy (Scholl & Tremoulet, 2000). This study was based on such simple displays and able to show that changes in amplitude, frequency, and similar motion cues affect judgments of personality. Although their ecological validity is in question at this state, the result obtained here support empirical studies that found impression formation to be influenced by kinematics features of body motion. Moreover, if applied in concert with research on natural behavior, the methodology presented could provide new insights into how people process nonverbal information.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jrp.2011.04.003.

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