Perception of Emotion and Personality through Full-Body Movement Qualities: a Sport Coach Case Study

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Virtual sport coaches guide users through their physical activity and provide motivational support. Users' motivation can rapidly decay if the movements of the virtual coach are too stereotyped. Kinematics patterns generated while performing a predefined fitness movement can elicit and help to prolong users' interaction and interest in training. Human body kinematics has been shown to convey various social attributes such as gender, identity and acted emotions. To date, no study provides information regarding how spontaneous emotions and personality traits together are perceived from full-body movements. In this paper, we study how people make reliable inferences regarding spontaneous emotional dimensions and personality traits of human coaches from kinematic patterns they produced when performing a fitness sequence. Movements were presented to participants via a virtual mannequin to isolate the influence of kinematics on perception. Kinematic patterns of biological movement were analyzed in terms of movement qualities according to the effort-shape [Dell 1977] notation proposed by [Laban 1950]. Three studies were performed to provide an analysis of the process leading to perception: from coaches' states and traits through bodily movements to observers' social perception. Thirty-two participants (i.e., observers) were asked to rate the movements of the virtual mannequin in terms of conveyed emotion dimensions, personality traits (five-factor model of personality) and perceived movement qualities (effort-shape) from 56 fitness movement sequences. The results showed high reliability for most of the evaluated dimensions, confirming inter-observer agreement from kinematics at zero acquaintance. A large expressive halo merging emotional (e.g., perceived intensity) and personality aspects (e.g., extraversion) was found, driven by perceived kinematic impulsivity and energy. Observers' perceptions were partially accurate for emotion dimensions and were not accurate for personality traits. Together, these results contribute to both the understanding of dimensions of social perception through movement, but also to the design of expressive virtual sport coaches.

Categories and Subject Descriptors: **H.5.2 [Information Interfaces and Presentation]**: User Interfaces—*Evaluation/methodology*; **J.4 [Computer applications]**: *Social and behavioral sciences: Psychology*.

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1. INTRODUCTION

Nonverbal behaviors are essential to communication, providing social meaningfulness to everyday human-human interactions. Affects, attitudes and personalities are pervasively conveyed through several modalities, including vocal, facial and bodily expressions [Giles and Le Poire 2006]. As the domain of affectively aware technologies grows, more knowledge is required to guide the design of affective interactive systems [Petta et al. 2011]. Virtual sport trainers are one these interactive technologies. With the lack of daily physical activity being one of the main health risk factors in our

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modern societies, virtual trainers are sport-oriented applications (e.g., tai-chi, biking, fitness), which can provide physical training programs with performance feedback and motivational support [Lowe and ÓLaighin 2012]. These physically engaging games – the so-called exergames – are now flourishing. In the case of a personal anthropomorphic virtual coach which guides the user in a physical activity (such as a fitness coach), the social aspects (dispositions, attitude and affects) conveyed during the interaction are key determinants of the quality of the relationship between the user and his personalized virtual trainer [Raedeke 2007, Jackson et al. 2011]. In addition, enjoyment has been recurrently found as a key determinant of energy expenditure [Lyons et al. 2014] and physical exercising [Dacey et al. 2008].

The context of this paper is the design of a full body interactive virtual coach that can convey social attributes through its bodily expressive kinematics patterns (motion described through space and time variations [Runeson and Frykholm 1983]. Of particular importance is the possibility to control the social perception formed by users while engaging with the virtual coach. Whilst empirical studies regarding the embodied nature of social phenomena accumulate, it appears difficult to draw general guidelines from this fragmented body of studies for the design of our specific application [Kleinsmith and Bianchi-Berthouze 2013]. First, only a few recent studies focus on kinematics patterns in bodily communication and evaluate the corresponding social perceptions [Gross et al. 2010]. Second, to date, no study has proposed to analyze conveyed social cues within the context of a coach performing a predefined fitness movement sequence. To overcome this gap, we previously collected predefined sport movement sequences performed by several coaches in different emotional contexts. The resulting corpus includes variability in dispositional and affective states (blinded). Importantly, the protocol was designed to collect spontaneous behaviors from individuals who were not familiar with acting methods.

The aim of this paper is to study whether emotions and personality traits are accurately perceived through kinematics patterns of bodily movements in the context of a fitness coach, who continuously guides the non-expert user through the movements to be performed. Kinematic patterns of movement were analyzed in terms of movement qualities according to the effort-shape notation [Dell 1977] proposed by [Laban 1950]. Three analyses were performed to provide an analysis of the process leading to the perception: from coaches' states and traits through bodily movements to observers' social perception. More specifically, thirty-two individuals were asked to rate movements in terms of conveyed emotion dimensions, personality traits (five factor model of personality) and perceived movement qualities (effort-shape) from fifty-six fitness movement sequences. The results from this analysis can contribute to both the understanding of social perception through full body movement [Thoresen et al. 2012] and the development of expressive virtual sport coaches [Tilmanne and Dutoit 2012], a virtual coach conveying motivation and positivity being more enjoyable than a neutral one.

2. RELATED WORKS

The communicative value of movement qualities has been studied with several approaches coming from different scientific backgrounds. The first subsection below aims at reviewing these varied origins and providing more details for the approach used in this paper: the effort-shape [Dell 1977] analysis method of the Laban notation system. The following two subsections survey works on associations between movement qualities and two social phenomena that are important for modeling a virtual full body coach: emotion and personality. Both kinematic patterns of bodily expressions and perceptions of emotion and personality are reviewed. Interactions between observed personality and emotion (whether expressed or perceived) are discussed because the overall impression made by the observer is often a merging of both dimensions. The last subsection considers essential methodological aspects when studying the perception process from bodily expression to perceived social cues.

2.1 Communication through movement qualities

Nonverbal communication involves different channels such as voice, face, body and touch [App et al. 2011]. Bodily behaviors are themselves decomposed into different types of cues. For a long time, gestures (specific isolated movements with a clear onset and offset) [Kendon 1994] and postures (static full body geometrical configuration) [Bull 1987] have been at the heart of bodily communication research [Dael et al. 2012]. Common to both typologies is the process of forcing a continuous behavior into a series of discrete events [Grammer et al. 1997]. An alternative option is to embrace the analog dynamics of human behaviors. Movement kinematics can be defined as "the way in which human movements are executed with respect to the dimensions of time and space" [Wallbott 1985]. "How" the movement is performed is not necessarily "expressive", which implies an intention to communicate, but is rather "distinctive". The contribution of motion alone to the communication of social cues has been evidenced with point-light displays developed by [Johansson 1973].

Movement quality is the subjective description of the objective measure of human kinematics often related to its inner dynamics [Runeson and Frykholm 1983]. One approach for studying movement quality has been to analyze semantically the subjective kinematic descriptions of behaviors [Wallbott 1985, Gallaher 1992, Shikanai et al. 2013]. These works revealed remarkable consistencies in their results with a recurring four-factor structure. These movement quality dimensions are space (or expansiveness, expansion), intensity (or expressiveness, dynamics), fluency (or coordination, stability) and hastiness (or animation). Structural approaches propose notation systems adapted for the detailed description of movement dynamics [Birdwhistell 1972, Sheets-Johnstone 1999]. The notation system proposed by [Laban 1950] has been used in dance studies and more generally in studies of bodily expressive communication. The Laban movement analysis (LMA) framework is composed of four main categories (body, effort, shape and space) that qualify the body in movement with respect to inner intentions. The effort-shape subdomain has received considerable interest as a systematic way of describing body configurations and movement qualities [Dell 1977, Levy and Duke 2003]. Effort is composed of four bipolar components including space (indirect/direct), weight (light/strong), time (sustained/sudden) and flow (free/bound). Space refers to "the way the body sculpts itself in space" [Laban 1950]. Shape flow, its first component, relates to the form of the body itself (growing or shrinking). The other two components, directional change and shaping movement, characterize the attitude toward an external object. Interestingly, the Laban conceptualization is not so different from the experimental results from semantic studies. They all include not only kinematic descriptions of motion but also perceived dynamic properties. Because human kinematics inherently reveal its underlying dynamics, the human observer tends to directly perceive the causal aspect of movement: for example, we perceive the effort behind the movement of man lifting a heavy load [Runeson and Frykholm 1983].

Several quantifications of these movement qualities have been proposed. In a seminal work, [Camurri et al. 2003] proposed a quantification of the Laban effort domain based on computer vision algorithms. Space, weight, time and flow were inferred based on automatically computed activity and expansiveness time series extracted from video. Other solutions for the effort-shape systems have been proposed [Samadani et al. 2013, Dyck et al. 2013] in addition to quantifications based on [Wallbott 1985] or [Gallaher 1992] works (see [Pelachaud 2009] and [Glowinski et al. 2011]). All of these quantifications are based on kinematic variables. An understudied research question is the validation of the correspondence between the quantifications (e.g., computed fluency) and the perceived movement qualities (e.g., perceived fluency). Several early works reported good correspondence between perceived and actual movement qualities [McGowan and Gormly 1976, Wallbott 1985]. Only one paper examined this question with modern quantification tools [Samadani et al. 2013]. The comparison between manual annotation by a certified movement annotator and the computed movement qualities revealed a high agreement across the effort-shape domain for acted arm movements. The associations between untrained observers' ratings and quantified movement qualities in a wider variety of movements remain to be studied. In the following sections of the paper, we make the distinction between perceived movement qualities as *proximal percepts* and computed movement qualities as *distal cues* [Scherer 1978, Scherer 2013].

In summary, movement qualities are subjective descriptions of the motion dynamics based on kinematic information that convey social cues. They can be described with a few dimensions. The Laban effort-shape system offers a way to systematically characterize them. Kinematic quantifications have been proposed, but their correspondence with non-expert human observations remains to be studied. The great potential of movement qualities as a communication modality relies on this direct perception of other inner forces and constrains (dynamics) and their potential associations with intentions (tendency to act) and emotions.

2.2 Movement qualities and emotion perception

An emotion is a relatively brief multi-component (cognitive, motor, physiological, and phenomenological) episode which facilitates a response to an event of significance for the organism (Davidson et al. 2003). Although we usually refer to emotions as states, the affective process is a *changing state* and is therefore dynamic. [Sheets-Johnstone 1999] explains the relation between emotion and movement by the congruency of their qualitative dynamics. The main theoretical framework used to predict motion-emotion congruencies is action tendencies [Frijda 1986]. Mainly described as discrete phenomena, emotions can alternatively be studied with dimensional approaches [Scherer 2010]. Valence (intrinsic pleasantness of the emotion-eliciting object), arousal (degree of physiological activation) and potency (individual's sense of control over the emotion-eliciting event) are the principal axes used. These dimensions have been shown to meaningfully explain differences in affective bodily expressions, even when the protocol is aimed at eliciting categorical emotions [Dael et al. 2013].

Previous studies have shown that movement qualities such as *proximal percepts* (perceived movement qualities) are associated with emotion recognition. At a general level, [Atkinson et al. 2004] showed that the perceived exaggeration of acted movements increases the emotion perception accuracy and perceived emotion intensity. Authors supposed that this general qualitative evaluation was driven by speed and expansiveness. Using sign language, [Hietanen et al. 2004] demonstrated the importance of movement qualities for emotion recognition. The association between high emotional arousal (interchangeably called activation [Gross et al. 2010], intensity [Atkinson et al. 2004] or emotion quantity [Wallbott 1998]) and a combination of high velocity, energy, force, directness and expansiveness is a recurrent finding [Wallbott 1998, Montepare et al. 1999, Gross et al. 2010, Gross et al. 2012, Dael et al. 2013, Crane and Gross 2013]. This has been attributed to the physical effort mobilization or the state of readiness to act provoked by a high arousal [Frijda 1986]. Discrimination of emotions according to valence is less consistent across studies. Fluency has been found to differentiate anger (less fluent, jerkier) from elated joy (more fluent) [Montepare et al. 1999, Dael et al. 2013]. Other studies highlight the role of expansiveness, which is greater for elated joy than for sadness [Gross et al. 2012, Crane and Gross 2013]. In terms of action tendencies, a negative feeling is observed to be associated with the tendency to flee, whereas a positive feeling is related to free activation [Frijda 1986]. This is a non-specific motor response, and it probably participates to the difficulty in recognizing it [Fredrickson 1998].

Works based on movement qualities as *distal cues* (kinematic cues) demonstrated a similar pattern of results. With movement purposely performed with different movement qualities, [Meijer 1989] distinguished three dimensions: rejection-acceptance related to strength and directness of the movement, withdrawal-approach associated with moving inward or outward, and preparation-defeatedness (associated with surprise) related to sudden, fast and direct movement. Arousal is consistently associated with velocity and acceleration [Pollick et al. 2001, Glowinski et al. 2011, Gross et al. 2012]. [Glowinski et al. 2011] found that in cases of high arousal, jerkiness is enabled to distinguish between negative and positive emotions. Even if the clustering algorithm defined by these authors performed well, the pattern was less distinctive for low arousal emotions. When emotion was induced in dancers, happiness-related expressions were observed to be expended more and were more impulsive than expressions of sadness [Dyck et al. 2013]. Kinematic patterns of bodily expressions of emotions have often been studied with gait analysis. Speed often came out as a main discriminative feature [Roether et al. 2009]. Other critical features proposed are specifically based on gait biomechanics models and, therefore, are not interpretable in terms of movement qualities [Barliya et al. 2013].

Whether distal or proximal, movement qualities have been shown to be related to emotional dimensions. High arousal is consistently associated with more energy and speed. Differences in valence show a less evident influence on movement qualities and are probably more dependent on the task. One possible issue is the interaction with the arousal dimension: valenced bodily expressions are different under low or high arousal emotions, with high arousal being easier to discriminate than low arousal valenced emotions. Finally, most of these studies are based on actors instructed to portray emotions. While it ensures high recognition rates of emotional movements, it also limits the applicability of the results to real word situations [Gross et al. 2010].

2.3 Movement qualities and personality perception

Personality traits describe individuals' invariant characteristics across both time and situations. While several models have been proposed to capture people traits, the five-factor model of personality has been shown to be the most robust [Costa and McCrae 1992]. This model characterizes an individual's personality across five broad traits, namely, extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience [John et al. 1991].

Personality traits have been observed to be visible in nonverbal behaviors whether self-reported or judged by others. The self-reported trait most assumed to be linked to nonverbal behaviors is extraversion [Gifford 1991, La France et al. 2004]. Often associated with more energetic and expressive behaviors, extraversion is consistently associated with cheerful expression [Hall et al. 2008]. This is coherent with the description of extrovert people as impulsive and uninhibited individuals [John et al. 1991]. Other traits may have a more contextual influence on nonverbal behavior: agreeableness will influence behaviors in a social context [Berry and Hansen 2000]. Neuroticism will modulate reactions in situations that induce negative affects [Gross and John 1995, Riggio and Riggio 2002]. Few studies analyzed the association between self-reported personalities and their associated bodily kinematics (distal cues). [Naumann et al. 2009] found extraversion associated with energetic stances and with agreeable and emotionally stable people standing in a more relaxed way. Using a music-induced movement paradigm, [Luck et al. 2010] found that extraversion and neuroticism were the two traits most related to body movement variables. They conclude to a concordance with the literature that extroverts are energetic and expressive, whereas neurotic people display reduced, localized and jerkier movements.

Judged personality has also been studied in relation to perceived movement qualities (proximal percepts). Studying political speech, [Koppensteiner and Grammer 2010] show that agreeableness is associated with a low level of activity and variability in verticality movements, extraversion with high activity and small movement fluctuations, and openness to experience with movement direction changes, and finally that neuroticism was associated with smooth transitions. These findings were confirmed in a subsequent study with a different protocol [Koppensteiner 2013]. During gait analysis, movements were reduced to two components evaluated on the effort-shape domain of the Labanotation system [Thoresen et al. 2012]. Agreeableness, extraversion and openness were positively associated with perceived spatial extent. Neuroticism was negatively associated with indirect, sustained and relaxed movement qualities. In all of these experiments, reliability was good, confirming the consensus at zero acquaintance (when observers have no prior knowledge of the person) from movement kinematics only. The two consistent findings emerging from these studies (perceived extraversion associated with movement activity and perceived neuroticism associated with movement jerkiness) are coherent with the literature on self-reported personality [Riggio and Riggio 2002]. However, having personality impressions based on good general rules (e.g., extroverts have energetic movements) does not necessarily lead to accurate judgment. When general physical appearance is available, only extraversion is accurately judged from the energetic stance [Naumann et al. 2009]. With only gait kinematics available, no associations between perceived and actual personality ratings were found [Thoresen et al. 2012].

While personality judgments have been observed to be strongly influenced by emotional expressions and evaluation of faces, only one study provides information regarding this phenomena for movement kinematics [Thoresen et al. 2012]. Perceived positive valence was strongly associated with adventurousness, extraversion, trustworthiness and warmth, and perceived high arousal was moderately correlated with adventurousness, extraversion and neuroticism. This phenomenon has been called *temporal extension* [Zebrowitz et al. 2007] or *overgeneralization* of emotional cues [Montepare and Dobish 2003].

Overall, self-reported and judged personalities have been shown to be related to movement qualities (distal or proximal) but without any evidence of accuracy. Observers form reliable and coherent social perceptions regarding the target person but misinterpret these available cues, merging personality traits and emotional dimensions via an overgeneralization process.

2.4 Methodological aspects

Studies on nonverbal behaviors often analyze the different components of the perception process separately: people states and traits, bodily expressions, perceptions of bodily expressions and people states and traits. To account for the whole process, some research paradigms have been proposed to structure the domain. The Brunswikian lens model is by far the most widely used [Brunswik 1956]. It is composed of three variables: a *distal psychological variable* (e.g., a personality trait) and several *available cues* (e.g., nonverbal behaviors) from which a perceiver makes an imperfect evaluation (e.g., perceived personality) of the distal variable (*evaluated criterion*). The gap between the *distal psychological variable* and *available cues* is called the *ecological validity*. *Cue utilization* is the association between *available cues* and *evaluated criterion*. Accuracy, which is the correlation between the *distal psychological variable* and *evaluated criterion*, is called *achievement*. Several of the studies reviewed in this paper refer to this model directly to structure their analysis [Gangestad et al. 1992, Bernieri et al. 1996, Naumann et al. 2009]. An extension of the model [Scherer 2013] proposed by [Scherer 1978] contrasts the *available cues* from the Brunswikian lens into *distal cues* (measured and quantified cues) and *proximal percepts* (evaluation of cues). This part of the analysis is called *perceptual representation*. The research presented in this paper is structured following this approach.

This paper presents an analysis of co-variations of the different variables from the four lens components. To do so, multiple Pearson correlations are presented, the multiplication of variables making them numerous. Such an approach raises the question of multiple comparisons which increase type 1 error risks (i.e., false positives). A common practice has been to adjust the p-value threshold for significance according to the number of tests done, such as with the Bonferroni method. In addition to being inconsistent (methods and scopes of adjustments vary across authors), such an approach is highly conservative drastically increasing the risk of type II error (i.e., false negative). Alternatively, Confidence Intervals (CI) provides information to interpret significant and non-significant results and enable the computation of meta-analyses [Nakagawa 2004, Cumming and Finch 2005]. As a consequence, in this paper we systematically report correlations (which are effect sizes) and confidence intervals (with a standard confidence level of 95%). If the interval includes the 0.0 correlation, then the null hypothesis cannot be rejected. Bootstrapping procedures (n=5000) are used to compute CI to remove the potential bias of relying on a hypothesized distribution.

Lastly, when one behavior is judged by several observers, the overall rating can be summarized in two ways: by aggregating the observer response and then model it or by modeling it for each observer and after average the models together. The first (mostly used) approach is a consensus or pooled rating [Kenny 1991]. This measure is interesting when ones is interested by impression made to a small group, like a committee [Ambady et al. 2000]. It is often confounded with the second approach which models the “typical observer” rating. These two ways of treating judgments are also called nomothetic and idiosyncratic judgment and are subject to considerable debate [Philippe et al. 1981]. Few articles undertook the approach to compute both [Bernieri et al. 1996, Naumann et al. 2009]. In this paper, we are interesting in the impression formed while watching a fitness coach. This context induces that the impression is rather made by a small group following the coach, thus we opted for a consensus approach.

2.5 Points addressed in this paper

The aim of this paper is to study the extent to which spontaneous emotions and personality traits are perceived through full body movement qualities performed by sport coaches with non-expert observers in the context of a fitness coaching task. Knowing what drives social perceptions and whether they are accurate will provide us guidelines and labeled data for the design of a full body virtual interactive sport coach to provide a personalized coaching experience. For clarity purpose, in this paper “participants” refer to individuals who participated in the perceptual study (i.e., also observers or raters) in opposition to coaches who performed the movement sequences.

The originality of our approach resides in several points. First, the analysis is based on a corpus of self-reported measures and motion capture data of non-acted behaviors: coaches (with their inter-individual differences in terms of personality) performed the same predefined movement sequence several times and under different contexts, eliciting different emotions. While movement variations might be very subtle (and less perceivable than the ones collected using acted protocols), they are spontaneous per se (i.e., not activated from an internal model of each emotion and personality trait). Second, the kinematic variations of the motion sequences are analyzed both as distal cues (computed movement qualities) and proximal percepts (perceived movement qualities) using the effort-shape characterization proposed by [Laban 1950] and [Dell 1977]. This enables us to analyze their pairwise similarities (e.g., computed weight with perceived weight) called *perceptual representation* for the first time in non-expert observers. We expect to have positive pairwise correlations between the kinematics-based computation of movement qualities and untrained observers perceived movement qualities. Finally, we assessed both self-reported and judged emotions and personality traits to have a complete understanding of how non-expert observers perceive the nonverbal behaviors performed by the coach. For both social phenomena, *ecological validity, cue utilization* and *achievement* are assessed. For the perception of emotions, we expect high self-reported and perceived arousals to be related to a high value of energy (weight) and impulsiveness (time). We also hypothesize that arousal will be the only dimension accurately evaluated by observers because several studies observed that this dimension is the most clearly related to bodily behaviors [Glowinski et al. 2011]. Given inconsistent results from the literature and the novelty of our task, we cannot draw expectations for the valence dimension. For the perception of personality traits (according to the five-factor model of personality), we expect extraversion and neuroticism to be related to computed movement qualities [Riggio and Riggio 2002]. Coaches with high-level scores of extraversion should be higher on computed energy (weight) and impulsiveness (time) than coaches with lower level scores of extraversion. Coaches with a high level of neuroticism should be lower on computed smoothness (flow) and spatial extent (shape qualities) than Coaches with a lower level of neuroticism. Given the novelty of our task and the few available results regarding studies with kinematics only, no a priori specific hypothesis can be formed regarding perceived personality traits. Based on previous studies, we expect observers to be inaccurate in personality trait evaluations [Thoresen et al. 2012].

3. CORPUS OF SPORT MOVEMENTS IN AFFECTIVE CONTEXTS

The perceptual study presented in this paper is based on a corpus of predefined movement sequences performed by coaches with different personalities under different emotional contexts. The collection of this corpus is extensively described elsewhere (blinded). The following section details aspects that are specifically relevant for the scope of this paper.

3.1 Coaches and Materials

Twenty French sport science students (mean age = 21.3, SD = 1.7, 11 females) participated in the study. Coaches' movements were collected with a full body motion capture system. The marker setup was composed of 36 markers (full body marker set provided by the Optitrack motion capture software). The experiment room was equipped with 10 infrared cameras (S250e Optitrack system, frequency: 120 Hz, resolution: 832*832). Each Coach received one week before the experiment a video of the motion sequence to be performed. All coaches received the same movement sequence in order to only analyze kinematics variations. They had to learn before arrival this movement sequence involving the whole body. The choreography was composed of two different foot movements (i.e., step, mounted knee), repeated twice for each side, two different arm movements (i.e., waved arm, uppercut) twice for each side, and two combinations of each previous foot and arm movement (i.e., step/wave, mounted knee/uppercut) repeated twice for each side (Figure 2 shows key frames of the motion sequence as an example). In each condition of the protocol (four conditions), the coach was asked to repeat this whole choreography three times (average length of the three repetitions of 1'30 minute). The general instruction was to perform the choreography in the *best possible way*.

3.2 Emotional contexts

Each coach performed the movement sequence under four different conditions to induce variability in terms of emotional experience. First, the protocol began with the control condition: performing the movement sequence without any context. The three other conditions –*positive*, *negative*, and *motivated*- were counterbalanced across coaches. In the positive condition, the coach received a reward for his participation (food and electronic devices of 10€ value) and watched a 1:30 minute mash-up of funny videos as a distraction task. In the negative condition, the experimenter explained to the coach that the video of the performance would be streamed in real-time at a remote lecture hall in front of hundreds of students for pedagogical purposes. Finally, in the motivated condition, the coach was asked to imagine him/herself as a fitness trainer who had to motivate his/her audience.

3.3 Movement qualities computation

Movement data were processed using Matlab R2012b. Positions from nine segments were used (one marker position used): hip, chest, head, arm, forearm, hand, upper-leg, leg, and foot. Five movement qualities were computed for each segment to model the effort-shape domain proposed by Laban [Laban 1950]: *impulsiveness* (time), *energy* (weight), *directness* (space), *smoothness* (flow) and *spatial extent* (shape qualities) (synonyms given in Table 1). A standard average is used for impulsiveness and smoothness, a weighted average is used for energy (weighted by members' masses) and the computation of spatial extent use the distance of hands and feet to the mass center. We obtained one time series per movement sequence per movement quality. Equations to model these qualities are described in Appendix A. Because our protocol predefines the movement trajectory, the directness index will only vary according to speed. Therefore, we do not consider it in the analyses.

3.4 Emotion and Personality Assessment

Experienced emotions and personality traits were assessed by self-reporting. Self-reported emotion states were assessed with the differential emotional scale [Ouss et al. 1990]. While most of the labels were not used by coaches (i.e., all coaches reported to not feel these labeled emotions), two labels showed good variability across coaches and conditions: *enjoyment* and *surprise* (blinded). In a dimensional view of emotions, enjoyment represents the valence dimension (i.e., positive) and surprise is associated with the activation dimension [Alvarado 1997]. Personality traits were considered regarding the five-factor model [Costa and McCrae 1992], which characterizes an individual's personality across five broad traits, namely, extraversion, agreeableness, conscientiousness, neuroticism, and openness [John et al. 1991]. The French version of the Big Five Inventory was used [Plaisant, Courtois, Réveillère, Mendelsohn, & John, 2010].

4. PERCEPTUAL STUDY

The aim of this perceptual experiment is to collect social perceptions formed by individuals watching expressive movement sequences performed by a sport coach. To do so, individuals evaluated movement sequences from our corpus on perceived movement qualities, perceived emotion and perceived personality. To isolate the influence of kinematics on perception from other sources of information (e.g., facial expressions, clothes, etc.), we used as stimuli 3D animations that were designed from the motion capture data described in the precedent section. Three studies provide an analysis of the perception process for bodily signatures of emotion and personality traits (expression, information transmission and perception) of coaches through movement qualities.

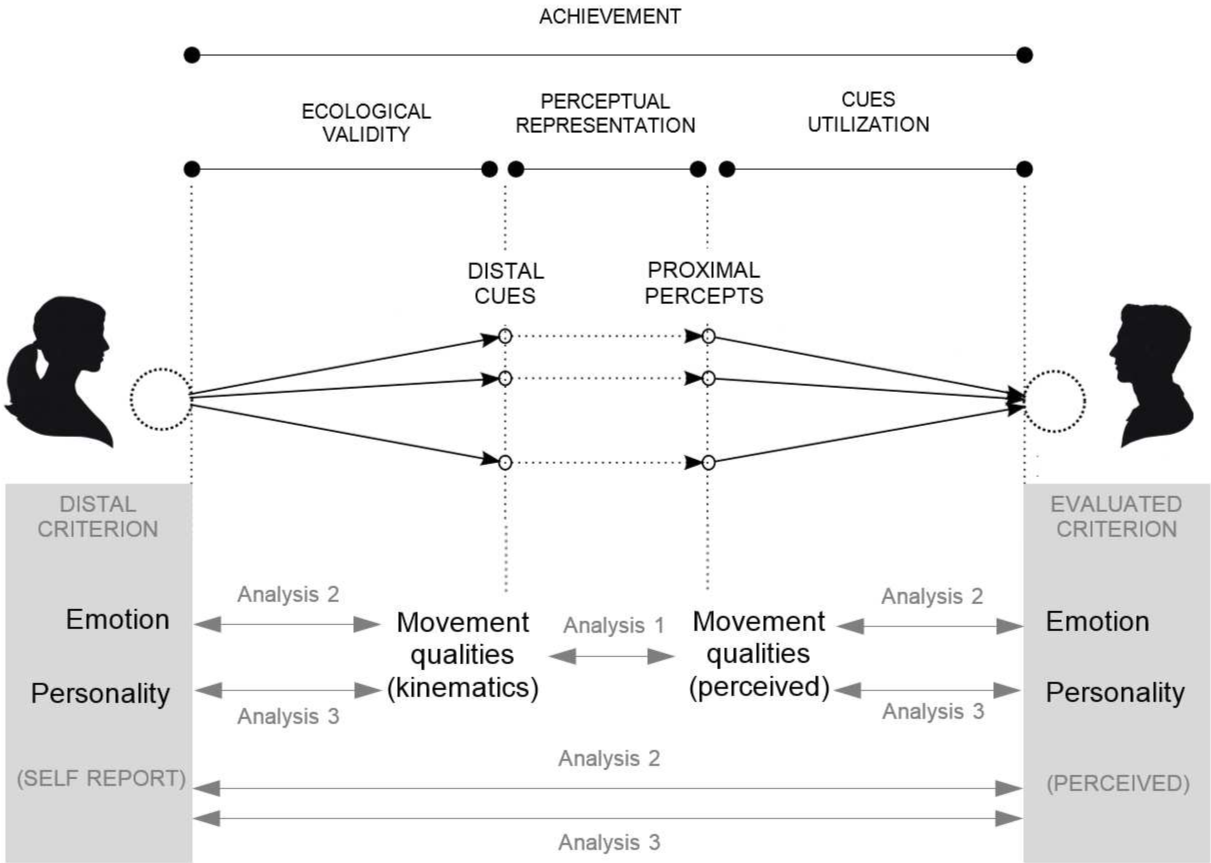
4.1 Method

*4.1.1 Analysis framework***.** To structure the analysis of the perception process composed of the expression, transmission and perception of social cues, we follow the paradigm proposed by [Scherer 1978, Scherer 2013]. As depicted in Figure 1, the framework describes four elements: distal environmental criterion (e.g., personality traits), distal cues (e.g., movement speed), proximal percepts (e.g., perceived movement speed) and evaluated criterion (e.g., perceived personality traits). These four elements are studied via four analyses: *ecological validity, cue utilization*, *achievement* and *perceptual representation*. In this paper, we organize them in three studies. First, the *perceptual representation* of movement qualities is analyzed. Validating the assumed inherent link between kinematics and the perceptual aspects of these qualities is a key point to understanding the decoding process. Second, *ecological validity, cue utilization* and *achievement* are studied for the communication (recognition-identification) of emotional states. Finally, *ecological validity, cue utilization* and *achievement* are studied for the communication (recognition-identification) of personality traits.

4.1.2 Participants. Thirty-two French participants were involved in this unpaid online perceptual study (mean age = 32.6, SD = 15.7, 15 females). The perceptual test was made available online. Participants were contacted by email with only information on the approximate survey duration and the conditions to undertake the survey: placed in a quiet place with good Internet access and seated at a comfortable distance from the screen. Participants were not paid.

4.1.3 Materials. A selection of one movement sequence in each condition from fourteen coaches of the corpus (n=20) was made to reduce the duration of the survey to ninety minutes. The fourteen coaches were chosen randomly. This resulted in 56 movement sequences of 30 seconds each. To control the effect of the physical appearance of coaches in the corpus (gender, size, weight, etc.) [Atkinson et al. 2004], a video was made of a 3D virtual mannequin playing the motion capture data. The 3D mannequin provided with the motion capture software was used. The animation being based on 3D joint rotations, the proportions of the mannequin remain the same across coaches. Each video was reframed to control the mannequin size. The viewpoint for the video was a front view as it is the common setup in pupil-coach tasks. Each video was preceded by a white fixation cross and followed by the display of one sentence asking the participant to complete the questionnaire. Figure 2 presents the key frames of one video stimulus as an example (to read from left to right, from top to down). Self-reported personalities (five-factor dimensions from the BFI-fr; [Plaisant et al., 2010]), self-reported affective experiences (enjoyment and surprise scales from the DES; [Ouss et al., 1990]) and computed movement qualities are known for each movement sequence.

Figure 1 The three analyses of this paper within the framework from [Scherer 2013], visual modified from [Vinciarelli and Mohammadi 2014]



4.1.4 Procedure. The first part of the instruction section described the general aim of the study as "the study of the movement expressivity of a virtual coach". It also recalled the structure of the survey. The second part presented the instructions regarding the good conditions that a participant should be in before continuing. It was made explicit that a good internet connection was required. In case of issues with video playing, participants had to inform us. One participant data was not taken in this study because of internet issues. It also explained the nature of the videos to be evaluated: every video is a different movement sequence but with the same appearance (a 3D virtual manikin). Nothing about the identities (body and face) or the conditions of the capture session was provided to the participant. The third part asked the participant for socio-demographic information (sex, age, practiced sport and level of expertise, contact). The following three pages provided detailed definitions regarding the dimensions to be evaluated for each video. These dimensions were grouped under three labels: movement qualities, emotions and personalities. For each dimension, a set of synonyms and a left and right anchor were provided to constitute a semantic differential scale. When possible, the labels were taken from the literature. At the end of each definition, participants were asked to report the clarity of the scale on a five-item Likert scale. Table 1 shows the dimensions with their associated left and right anchors (French versions are available in Appendix B). Each dimension is evaluated on a 10-item Likert scale.

Before the evaluation part, the participants viewed and rated three training trials. These trials were movement sequences that were not part of the set of sequences used in the perceptual study. All of the definitions were recapped at the bottom of the page to enable the participant to read them again if needed. For the evaluation part, the participant viewed and rated the 56 videos. The video order was randomized across participants but not the order of questions. At each page, all dimensions had to be rated to go on the next page.

Figure 2 Key frames of one video stimulus (as an example) presented to the participant (duration: about 30s)

** Fill out the questionnaire. Click on next when you are done. Thank you.*

4.1.5 Item clarity and Rater reliability. All of the dimensions were rated by participants as having very clear meanings, but the less clear dimension was Dominance (mean clarity = 4.25, on a five-item

Likert scale). Looking at the averaged pairwise inter-rater correlations averaged across all 15 dimensions, two raters were below the threshold of 0.20 (very low agreement with other raters). These two raters were removed from the study. We performed an outlier analysis on average scores and a standard deviation of the scores per participant on each of the 15 scales [Hoaglin et al. 1986]. Three raters were removed based on this analysis. A second outlier analysis on standard deviation across the 15 dimensions for each movement sequence aimed at looking for participant ratings systematically (when not taking seriously the survey, a standard deviation of zero means rating every scale with the same response).

Table 1 Evaluated dimensions with their left/right anchors and their raters' reliability indicators

Movement qualities	Left anchor[a]	Right anchor[b]	Average inter-rater correlations (r)	Spearman-Brown Coef. (R_{sb})	Cronbach alpha (α)
Smoothness	Abrupt	Smooth	0.18	0.89	0.86
Directness	Indirect	Direct	0.09	0.66	0.68
Energy	Limp	Energetic	0.53	0.96	0.97
Impulsivity	Restrained	Impulsive	0.46	0.95	0.96
Spatial extension	Restricted	Vast	0.41	0.95	0.95
Emotion	**Left anchor[a]**	**Right anchor[b]**			
Valence	Negative	Positive emotion	0.39	0.95	0.95
Intensity	Low intensity	Strong intensity	0.33	0.95	0.93
Dominance	Subdued	Dominant	0.37	0.93	0.94
Motivation	Without	Strongly motivated	0.40	0.95	0.95
Stress	Relaxed	Stressed	0.09	0.75	0.76
Personality	**Left anchor[a]**	**Right anchor[b]**			
Extraversion	Introverted	Extroverted	0.40	0.93	0.95
Openness	Humdrum	Adventurous	0.38	0.95	0.94
Neuroticism	Neurotic	Stable emotionally	0.17	0.87	0.84
Conscientiousness	Careless	Conscientious	0.08	0.65	0.67
Agreeableness	Disagreeable	Warm	0.31	0.93	0.92

[a] Score = 1

[b] Score = 10

(grey shading) = not acceptable reliability

This analysis revealed no supplementary outliers. Three different indicators of the raters' reliability were computed for the 30 remaining raters on each dimension (Table 1). The average inter-rater correlations show the amount of agreement, and the Spearman-Brown coefficient shows the effective reliability [Rosenthal 2008]. We also provide Cronbach's alphas (often reported as an alternative reliability indicator [Gross et al. 2010]). Three dimensions –Directness, Stress, Conscientiousness- showed very poor agreement ($r<0.1$) and reliabilities ($R_{sb}<0.8$ and $\alpha<0.8$) and were removed from the analysis. For the 12 remaining scales, the raters' scores were averaged (to obtain a consensus score) for each video for the analysis.

4.1.6 Correlation bias and General impression: selecting and transforming variables. A first look at bivariate correlations between evaluated dimensions revealed moderate to strong positive correlations between all dimensions ($r>0.6$). This high common variance was confirmed by a principal component analysis, suggesting a one-component structure accounting for 88.2% of the total variance. The existence of sizeable pairwise correlations between rated items is a recurrent aspect of judgment studies. This phenomenon has been coined the "Halo effect" [Thorndike 1920] or "Exaggerated emotional coherence" [Morewedge and Kahneman 2010], that is, the tendency to think of a person or an object in a generalized impression (as a whole). This exaggerated coherence is considered to be caused by raters' assumptions concerning the co-occurrence of rated items [Podsakoff et al. 2003]. Not considering this inherent multicolinearity in judgment studies can lead to methodological issues and ambiguous results [Kraha et al. 2012].

Before analyzing this general impression as a social perception characteristic of our task, one aspect should be controlled. This source of multicolinearity could result from a method bias: the duration of the survey and the number of items to be evaluated at the same time tend to increase the risk of correlation bias [Cooper 1981]. One way to clarify this issue is to compare the Halo effect in two judgment conditions, the second being hypothetically less subject to associative processes [Johnson 1963]. We designed three shorter versions of the test, each one with different dimensions to be evaluated (one with the five movement quality dimensions, one with the five emotional dimensions and one with five personality traits dimensions). Each test had only 20 movement sequences per rater. For these tests, the question orders were also randomized at each movement sequence. The duration was considerably reduced (24 minutes on average compared to 96 minutes on average for the long version). A multitrait-multimethod matrix (MTMM) [Campbell and Fiske 1959] was computed to compare the two methods (full matrix in Appendix C). A MTMM represents the pair-wise correlations between similar variables measured via different methods. Of particular interest for this paper are two diagonals: the reliability diagonal (using Spearman Brown formula) and the diagonal which indicate the inter-method correlation: they provide indication about the inter-method convergent validity. Table 2 presents these item reliabilities and inter-method correlations. Only the neuroticism scale showed no convergent validity across methods (the inter-method correlation is only about r=.243) and a very poor reliability in the short form of the test. This scale was removed from the study.

Table 2 Rated dimension characteristics

Dimensions		Nb of raters		Reliability		Inter-methods correlations	Observed / Residuals	
		Long	Short	Long	Short		r	CI
Movement qualities	Smoothness	27	10	0.89	0.81	.828	**.644**	**.471 to .784**
	Energy	27	10	0.96	0.86	.949	.233	-.026 to .497
	Impulsivity	27	10	0.95	0.86	.928	.242	.000 to .445
	Spatial	27	10	0.95	0.90	.901	**.486**	**.220 to .686**
Emotion	Valence	27	10	0.95	0.87	.805	**.260**	**.066 to .480**
	Intensity	27	10	0.95	0.91	.883	.280	-.007 to .510
	Dominance	27	10	0.93	0.88	.736	.267	-.015 to .543
	Motivation	27	10	0.95	0.83	.869	**.254**	**.041 to .454**
Personality	Extraversion	27	12	0.93	0.92	.888	.198	-.017 to .406
	Openness	27	12	0.95	0.88	.844	.113	-.190 to .382
	Neuroticism	*27*	*12*	*0.87*	*-0.16*	*.243*	-	-
	Agreeableness	27	12	0.93	0.84	.830	.363	**.156 to .554**

The 11 remaining scales can be considered free from method bias and subject to a large Halo effect. The existence of this strong general impression is not surprising given our task. Raters were asked to give their "first spontaneous impression" regarding very subtly different movement sequences without any contextual information. Given this high ambiguity, they relied on prior knowledge/beliefs and favored fast associative judgments based on the few salient elements. To disentangle the general impression from the specific component of the evaluation, we use a procedure similar to [Landy et al. 1980]. First, we extract the general impression (G) over the remaining 11 scales with an exploratory factorial analysis (EFA with the maximum likelihood estimation method). This method is more appropriate than a principal component analysis because its objective is to reproduce the intercorrelations of a set of indicators, recognizing a part of a unique variance for each [Brown 2006]. The second step is to partial out the general component from each variable by regressing them on G. Using the residuals as unique over the shared contribution of the predictors is often performed in cases of correlated variables [Graham 2003, Engell et al. 2007]. Extracted residuals from these regressions form the specific part of the evaluation. Correlations between observed and specific components for each scale are presented in Table 2 along with confidence intervals. For the rest of the analysis, we keep the specific components that correlate significantly with their observed part. They still contain a meaningful part of the observed variance once the general component variance is removed. It should be noted that these five residual variables represent a very small part of the observer ratings variance compared to the general impression dimension (88.2% of the variance) and caution should be taken in drawing conclusions about their associations.

This procedure provided a reduced number of variables: general impression (G), perceived smoothness (P-smoothness), perceived spatial extent (P-spatial extent), perceived valence (P-valence), perceived motivation (P-motivation) and perceived agreeableness (P-agreeableness). In addition to a considerably reduced multicollinearity in our data, the data provided a more representative picture of the discriminative power of the raters. This general impression G, composed mainly of impulsivity (r=.972), energy (r=.973), intensity (r=.962), dominance (r=.963), extraversion (r=.980) and openness (r=.994), seems coherent with the "overall expressive level of people's interpersonal behavior", working as an expressivity halo similar to [Bernieri et al. 1996]. Because they include movement qualities such as emotion dimensions and personality traits, the general impression G will be considered in the three studies.

4.2 Analysis 1: Perceptual representation of movement qualities

In this first step, we analyze the relations between movement qualities, computed or observed, within our corpus. Our aim is twofold: to understand how movement qualities are related to each other (e.g., is energy independent of smoothness?) and to assess the associations between untrained observers' ratings and quantified movement qualities.

4.2.1 Computed movement qualities. For each movement sequence, five movement qualities were computed to model the effort-shape domain [Dell, 1977] proposed by Laban: energy, impulsivity, directness, spatial extent and smoothness (Appendix A). Table 3 shows pairwise correlations between computed movement qualities for the 56 movement sequences from our corpus.

Computed energy and impulsivity are strongly and positively correlated (r=0.89). Computed smoothness is positively and moderately correlated to all dimensions (r>0.35). Computed spatial extent is moderately and positively correlated to computed energy (r=0.360). These results show a significant amount of shared variance across our movement qualities, with energy and impulsivity being very close dimensions.

Table 3 Pearson correlations and CI between computed movement qualities (n=56)

	C-energy	C-impulsivity	C-spatial	C-smoothness
C-energy	1	**0.89** **.822 to .935**	**0.36** **.106 to .573**	**0.50** **.382 to .619**
C-impulsivity		1	0.21 -.038 to .437	**0.42** **.269 to .550**
C-spatial extent			1	**0.37** **.159 to .592**
C-smoothness				1

4.2.2 Perceived movement qualities. On the perceptual side, three movement qualities are available: the general impression (mainly composed of energy and impulsivity), perceived smoothness and perceived spatial extent. Table 4 shows pairwise correlations between the perceived movement qualities for the 56 movement sequences of our corpus.

The general impression does not correlate with perceived smoothness and perceived spatial extent per se (shared variance removed). Perceived smoothness and spatial extent are orthogonal as well (r=0.093, p>0.050). For our corpus, the observers' perceptual realm is, therefore, composed of three independent variables.

Table 4 Pearson correlations and CI between perceived movement qualities

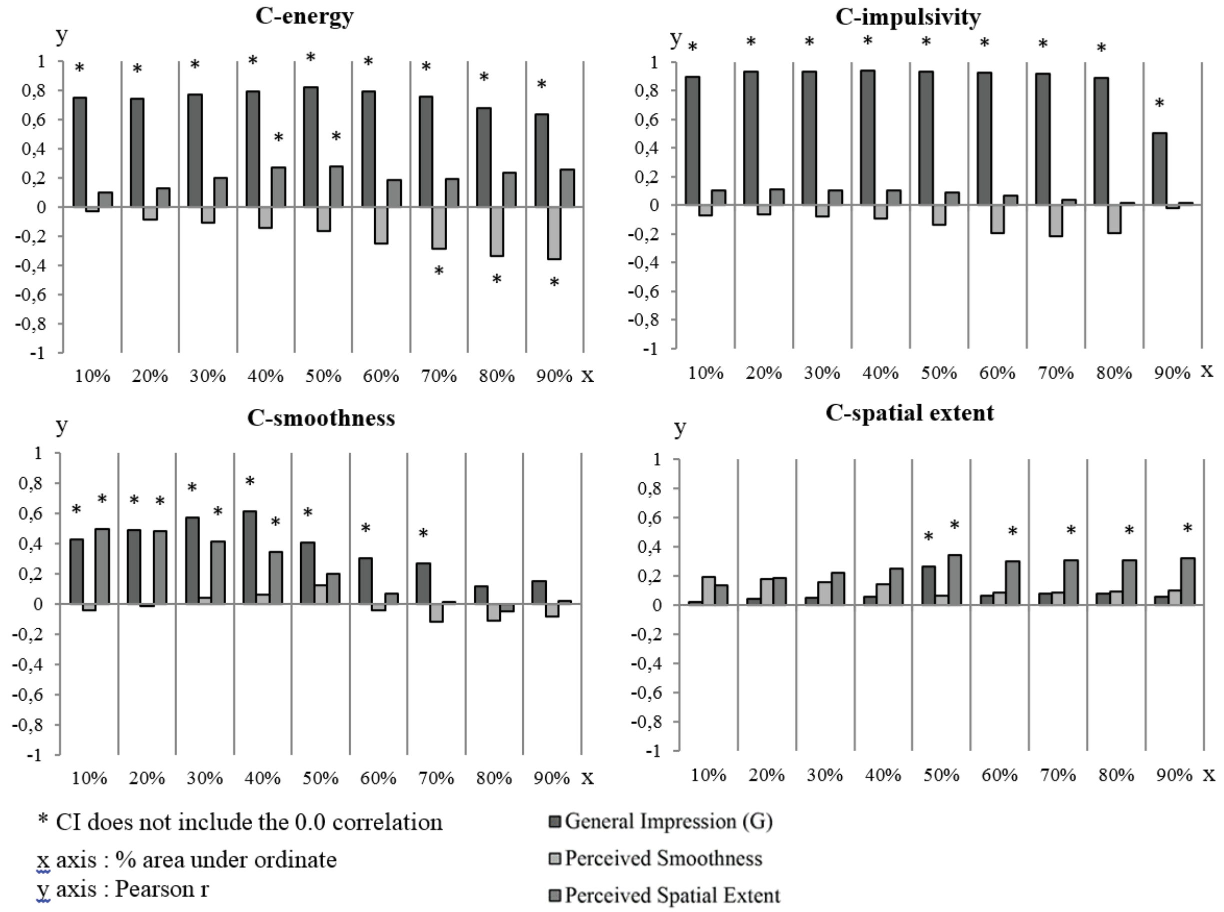
	G	P-smoothness	P-spatial extent
G	1	0.00 /	0.00 /
P-smoothness		1	0.09 -.112 to .345
P-spatial extent			1

* for p<0.05

** for p<0.01

4.2.2 Perceptual representation. Perceived movement qualities are not necessarily highly correlated to computed movement qualities means. For example, perceived energy could be more highly correlated to the computed energy peaks in time (which are more salient) than the computed energy mean. To analyze the relations between perceived movement qualities and a larger spectrum of movement qualities computations, we computed eight values around the mean representing intermediates between the minimum (=10%), mean (50% in figure 3) and maximum (=90%). Considering a time series, the mean (50% in figure 3) is a value where the area under and above the curve is equal (each represents 50% of the total area under the curve). The eight values computed are the ordinates, where the area under the curve is increased or decreased by 10%. In figure 3, each graph shows pairwise correlations between the three perceived movement qualities and the nine computed variables of the treated quality.

Figure 3 Correlations between computed and perceived movement qualities



Strong positive correlations were found between general impression G and computed energy (r=0.821 for 50%) and impulsivity (r=0.935 for 50%), regardless of the mean variations. G was positively and moderately correlated with computed smoothness (p=0.615, for 40%). Because the factor G is mainly composed of perceived impulsivity variance, these results show a high convergent validity between G and the computed impulsivity mean: the highest pairwise correlation and the same pattern of correlations with other computed qualities. There was a positive weak correlation between the perceived spatial extent and computed energy (r=0.274, for 50%), weak positive correlations between the perceived spatial extent and computed spatial extent (r=0.343, for 50%) and a positive and moderate correlation between the perceived spatial extent and low values of computed smoothness (r=0.496, for 10%). The first two results regarding the perceived spatial extent show partial convergence between the computed and perceived spatial extents. The negative correlation between the perceived spatial extent and low values of computed smoothness is less interpretable but does not impair the convergent validity because the computed spatial extent (for 50%) correlates positively with computed smoothness (r=0.323, for 10%). Perceived smoothness was negatively correlated with high values of computed energy only (r=-0.362, for 90%). Thus, perceived smoothness shows no convergent validity with computed smoothness. The perceptive variable was more associated with peaks of energy within the time series.

This first analysis shows that observers were highly accurate in evaluating kinematic impulsivity and energy. The perceived impulsivity and energy (the two dimensions are almost similar) seems to be the kinematic basis for the general impression G. Perceived spatial extent showed partial convergent validity and perceived smoothness with no convergence at all. Overall, untrained observers were only heterogeneously accurate, contrasting with previous studies showing good agreement between certified movement analysts and computed qualities. For the following two studies, we will keep both movement qualities and evaluations (perceived and computed) in the analysis.

4.3 Analysis 2: Emotion Analysis

In this second step, we analyzed the perception process of emotions through full body movement qualities, computed or observed, within our corpus. Our aim is twofold: to understand how movement qualities are related to self-reported and perceived emotions and to assess the accuracy of emotional perception.

4.3.1 Ecological validity and Cue utilization in emotion perception. For each movement quality (computed and perceived) and each emotion, we tested the extent to which the movement qualities correlated with the induced emotion (ecological validity). We also tested the extent to which movement qualities correlated with perceived emotions (cue utilization). Table 5 presents the ecological validity and cue utilization for emotions (self-reported and perceived).

Self-reported emotions show that computed and perceived cues correlate. Coaches' self-reports of enjoyment were positively correlated to the computed spatial extent and perceived general impression and were negatively correlated to the perceived spatial extent. Self-reported surprise was positively correlated with all cues but not with perceived smoothness. While felt surprise seems clearly related to the general impression and impulsivity (which share some variance with all computed movement qualities), the pattern for enjoyment is less clear: movements were found to be more expanded kinematically but perceived as being less expanded and more impulsive.

In terms of perceived emotion, the general impression G is interpreted as emotional intensity. Observers' perceptions of intensity were most strongly correlated with computed energy and impulsiveness and were moderately correlated computed spatial extent and computed smoothness. Observers' perceptions of valence were most strongly (negatively) correlated with perceived smoothness and were moderately (positively) correlated with computed spatial extent. Perceived motivation was only correlated with computed spatial extent. Overall, these results suggest different patterns in cue utilization for all three perceived emotions: movements perceived as being more positive (in affect) and motivated were recorded as more expanded whilst movement perceived more expressive were more impulsive. In the perceptual realm, valence and motivation differ in their association with perceived smoothness: only perceived affectively negative movements were related to movement perceived smoother.

Both in ecological validity and cue utilization, significant correlations exist between emotions (self-reported or perceived) and computed and perceived movement qualities. This means that sufficient information exists for the observer to form accurate perceptions of felt emotions: experienced emotions are kinematically encoded (i.e., embodied) and are correlated with perceived movement qualities, and these same computed and perceived cues are correlated with perceived emotions.

Table 5 Ecological validity and cue utilization for emotions (Pearson correlations and CI)

Ecological validity		*Perceptual cues*	*Cue utilization*		
S-enjoyment	S-surprise		*G*	P-valence	P-motivation
		Distal cues			
0.13 -.149 to .370	**0.43** **.138 to .644**	C-energy	**0.82** **.711 to .901**	-0.02 -.251 to .237	0.02 -.195 to .212
0.24 **.010 to .457**	**0.44** **.123 to .667**	C-impulsiveness	**0.94** **.894 to .963**	-0.15 -.362 to .097	-0.14 -.339 to .049
0.36 **.099 to .581**	**0.34** **.136 to .548**	C-spatial extent	0.27 -.007 to .493	**0.41** **.181 to .603**	**0.37** **.185 to .550**
-0.02 -.270 to .222	**0.40** **.235 to .569**	C-smoothness	**0.41** **.244 to .543**	0.14 -.295 to .553	0.24 -.092 to .535
		Proximal			
0.28 **.041 to .490**	**0.48** **.206 to .672**	G	1.00 /	0.00 /	0.00 /
-0.36 **-.526 to -.124**	0.27 -.046 to .504	P-spatial extent	0.00 /	0.22 -.011 to .401	0.13 -.137 to .342
-0.07 -.346 to .226	0.09 -.148 to .305	P-smoothness	0.00 /	**-0.65** **-.770 to -.483**	0.06 -.236 to .357

4.3.2 Achievement between self-reported and perceived emotions. For each emotion, we tested the extent to which the perceived emotions correlated with the coach's actual emotion (achievement) to find out if observers were accurate in their ratings. Table 6 presents the achievement for emotions (self-reported and perceived).

Perceived intensity (general impression G) was positively correlated with both self-reported enjoyment and surprise, more strongly with the latter. Perceived valence showed no significant correlations. Perceived dominance was positively correlated to self-reported surprise. These results demonstrate partial accuracy in observers' perceptions. Accuracy was nonexistent for valence (represented by S-enjoyment and P-valence, respectively) and moderate for arousal (represented by S-surprise and G, respectively). The association between general impression and felt enjoyment demonstrates that observers had difficulties to differentiate experienced enjoyment and surprise and that they rated them as almost being equally expressive. Perceived motivation correlation with felt surprise confirms the partial accuracy of observers in detecting emotion activation: motivation induces more energy expenditure (a component of arousal) even if positively connoted.

Table 6 Achievement for emotions (Pearson correlations and CI)

		Evaluated criterion		
		G	P-valence	P-motivation
Distal criterion	S-enjoyment	**0.28** **.041 to .490**	0.02 -.261 to .319	-0.07 -.320 to .199
	S-surprise	**0.48** **.206 to .672**	0.11 -.131 to .362	**0.20** **.008 to .399**

4.4 Analysis 3: Personality Analysis

In the third step, we analyzed the perception process of personality through full body movement qualities, computed or observed, within our corpus. The aim is twofold: to understand how movement qualities are related to self-reported and perceived personality traits and to assess the accuracy of personality perceptions.

4.3.1 Ecological validity and Cue utilization in personality perception. For each movement quality (computed and perceived) and each personality trait, we tested the extent to which the movement qualities correlated with the coach's actual personality (ecological validity) and the extent to which movement qualities correlated with perceived personality (cue utilization). Table 7 presents the ecological validity and cue utilization for personality (self-reported and perceived).

Self-reported personality traits showed that computed and perceived cues correlate. Coaches' self-reports of extraversion were positively correlated to the computed spatial extent. Self-reported openness was negatively correlated with computed energy, impulsiveness and perceived spatial extent. Self-reported neuroticism was positively correlated with general impression only. Coaches' agreeableness scores were negatively correlated with computed spatial extent and perceived spatial extent. Finally, self-reported consciousness was only positively correlated to perceived smoothness. These results show that movement qualities (perceived or computed) convey some information regarding individual personality traits: as in the literature, individual highs in extraversion make movement more expanded, but the other traits have their associations.

Table 7 Ecological validity and cue utilization for personality traits (Pearson correlations and CI)

Ecological validity					*Perceptual cues*	*Cues utilization*	
S-extra	S-openness	S-neuro	S-agreea	S-conscie		*G*	P-agreeableness
					Distal cues		
-0.10	**-0.29**	0.27	-0.14	-0.22	C-energy	**0.82**	-0.13
-.344 to .152	**-.484 to -.094**	-.012 to .509	-.398 to .115	-.473 to .045		**.711 to .901**	-.340 to .073
-0.03	**-0.26**	0.26	0.00	-0.09	C-impulsiveness	**0.94**	-0.19
-.237 to .178	**-.456 to -.072**	-.011 to .498	-.261 to .203	-.346 to .183		**.894 to .963**	-.386 to .000
0.55	-0.01	0.16	**-0.44**	0.02	C-spatial extent	0.27	**0.28**
.330 to .714	-.288 to .345	-.130 to .387	**-.674 to -.092**	-.238 to .284		-.007 to .493	**.075 to .492**
0.25	-0.02	0.22	-0.10	0.15	C-smoothness	**0.41**	0.25
.027 to .441	-.234 to .221	-.076 to .440	-.328 to .171	-.134 to .376		**.244 to .543**	-.083 to .525
					Proximal percepts		
0.04	-0.15	**0.40**	-0.00	-0.05	G	1.00	0
-.207 to .269	-.373 to .062	**.164 to .598**	-.279 to .248	-.325 to .216		/	/
0.06	**-0.39**	-0.06	**-0.29**	-0.13	P-spatial extent	0.00	0.01
-.206 to .335	**-.573 to -.178**	-.232 to .127	**-.487 to -.097**	-.367 to .107		/	-.210 to .206
0.23	0.04	0.30	0.10	**0.42**	P-smoothness	0.00	**0.57**
-.008 to .434	-.191 to .266	-.031 to .576	-.111 to .350	**.217 to .592**		/	**.343 to .736**

In terms of perceived personality traits, the general impression G is mainly composed of extraversion and openness. Observers' perceptions of extraversion and openness (within G) were most strongly correlated with computed energy and impulsiveness and moderately correlated with computed spatial extent and computed smoothness. Perceived agreeableness was positively correlated with computed spatial extent and perceived smoothness.

Both in ecological validity and cue utilization, significant correlations exist between personality traits (self-reported or perceived) and computed and perceived movement qualities. Only self-reported conscientiousness and neuroticism showed no computed movement quality correlations (although some were nearly significant). This suggests that sufficient information exists for the observer to form accurate perceptions of self-reported personality traits: personality characteristics are kinematically encoded and are correlated with perceived movement qualities. These same computed and perceived cues are correlated with perceived personality traits.

4.3.2 Achievement between self-reported and perceived personality. For each personality trait, we tested the extent to which the observers' perception of personality traits correlated with the coaches' actual personality traits (achievement). Table 8 presents the achievement for these traits (self-reported and perceived).

Perceived extraversion and openness (within the general impression G) were positively correlated with self-reported neuroticism. Perceived agreeableness showed positive correlations with self-reported extraversion and openness. These results demonstrate no accuracy in observers' perceptions of personality traits. Instead, their perceptions were associated with other personality traits, indicating wrong attributions. The wrong evaluation of self-reported neuroticism was probably caused by the mediating variable computed energy: aroused by the protocol, more neurotic people made more energetic movements than perceived by an extrovert and open personality person.

Table 8 Achievement for personality

		Evaluated criterion	
		G	P-agreeableness
Distal criterion	S-extraversion	0.04 -.207 to .269	**0.29** **.068 to .497**
	S-openness	-0.15 -.373 to .062	**0.27** **.047 to .491**
	S-neuroticism	**0.40** **.164 to .598**	0.09 -.197 to .379
	S-agreeableness	-0.00 -.279 to .248	0.10 -.176 to .403
	S-conscientiousness	-0.05 -.325 to .216	0.22 -.001 to .446

4.5 Discussion

The three studies presented in this paper aimed at contributing to our understanding of emotions and personality trait perception based only on kinematic information provided by full-body movements. The specific context of our task is a fitness coach who continuously guides non-expert users through the movements to be performed. Thus, task movement was a predefined sequence performed in various emotional contexts and varied according to the coach's personality. Kinematic patterns of movement were analyzed in terms of movement qualities according to the effort-shape notation [Dell 1977] proposed by [Laban 1950]. Thirty-two participants were asked to rate movements in terms of conveyed emotion dimensions, personality traits (five-factor model of personality) and perceived movement qualities (effort-shape) for fifty-six fitness movement sequences from our corpus.

Before conducting the three studies, the exploration of collected data from raters revealed that high intercorrelations were present between the evaluated dimensions (movement qualities, emotions and personality traits). Approximately 88% of the total variance could be explained by a unique component mainly composed of perceived impulsivity, energy, intensity, dominance, extraversion and openness. Although not often reported in the literature, this general impression is consistent with the interpersonal halo reported by [Bernieri et al. 1996]. These authors summarize this general impression as "what is expressive is good". Our methodological approach consisted of computing this general impression to form a new variable and to extract the specific variance of other variables to avoid multicolinearity. In the design of a virtual coach, this general impression would be the first variable to model because it conveys most of the positive attributes. Identifying the halo does not provide information about the sources of this perceptual generalization and future researches could attempt to identify them. The perceptual halo can results from "true" holistic judgment (i.e., even with more information, these associations would appear) or can be caused by the lack of relevant information in movement kinematics (the less the individual information the more she/he relies on assumptions which are more subject to holistic reasoning). As more ecological stimuli (i.e., with facial, clothes and context information) have been shown to induce accurate judgments about personality and emotions [Ambady et al. 2000], the second possibility seems more plausible. Future works could investigate how movement kinematic complements other sources of information in the process of impression formation. The following studies that we described decomposed the analysis in three steps: the first analysis considered the perceptual representation of computed movement qualities; the second analysis investigated how emotions are perceived through the kinematic modality; and the third analyzed how personality traits are perceived through the kinematic modality.

In analysis 1, the associations between computed and perceived movement qualities (called perceptual representation) were analyzed. The only previous work that compared manual annotation by a certified movement annotator and the computed movement qualities revealed a high agreement across the effort-shape domain for acted arm movements [Samadani et al. 2013]. In our work, with non-expert observers and spontaneous full body movement in contrast to our hypothesis, we found only partial convergence validity between movement qualities computed from kinematic variables and perceived movement qualities. The general impression G was accurately driven by movement impulsivity (amount of acceleration) and energy, but perceived spatial extent was only partially related to computed spatial extent and perceived smoothness was not related to computed smoothness. We also analyzed the relations between perceived movement qualities and a larger spectrum of computations of the effort-shape dimensions: this analysis revealed that perceived smoothness was correlated with higher values of energy. We can draw two conclusions from these results. First, the general impression conveying most of the expressive attributes is accurate: in the context of a virtual coach, varying movement impulsiveness/energy is the first parameter to explore. Second, for non-expert observers, how the kinematics is perceived is not necessarily what kinematics is: more study is required to evaluate what drives perceived smoothness and spatial extent. An alternative method would be to automatically explore possible computations of perceived movement qualities [Kikhia et al. 2014].

In analysis 2, the associations between movement qualities (perceived and computed) and emotions (perceived and self-reported) were analyzed. Based on previous works [Glowinski et al. 2011], we hypothesized that high self-reported and perceived arousals would be related to high values of energy (weight) and impulsiveness (time). We also hypothesized that arousal would be the only dimension accurately evaluated by observers. Our results partially confirm our expectations: felt surprise (considered as representing the arousal dimension) and enjoyment (considered as representing the valence dimension) were positively correlated to the general impression, revealing moderate accuracy and no accuracy, respectively [Gross et al. 2010]. The association between general impression and felt enjoyment demonstrates that observers were not able to differentiate experienced enjoyment and surprise and that they rated them as being equally expressive. While perceived valence was not accurate, perceived motivation showed partial accuracy with a positive correlation with self-reported surprise [Russell and Mehrabian, 1977, Dael et al., 2013]. From this analysis, we can conclude that in our fitness task, arousal and valence are dimensions that are perceptually merged within the general impression: a more impulsive coach will convey more positive and activated affects. Additionally, the weakness of the associations confirm the fact that spontaneous affects are more difficult to judge than acted ones.

In analysis 3, the associations between movement qualities (perceived and computed) and personality traits according to the five-factor model (perceived and self-reported) were analyzed. Based on previous works [Riggio and Riggio 2002], we hypothesized that coaches who rate high on extraversion should be higher for computed energy (weight) and impulsiveness (time) than coaches with lower level scores of extraversion, and coaches with a high level of neuroticism should be lower on computed smoothness (flow) and spatial extent (shape qualities) than coaches with a lower level of neuroticism. We also expected no accuracy in personality trait perception [Thoresen et al. 2012]. Our results confirm our hypothesis partially: as in the vast literature on personality, self-reported extraversion was observed to be related to computed spatial extent [La France et al. 2004]. Self-reported neuroticism showed different associations from our expectations: more neurotic coaches had more energetic movements and were perceived as more impulsive and smoother. We interpret this discrepancy from the literature as a result of our protocol: the act of performing a fitness movement in a motion capture suit in front of dozens of cameras can be considered arousing per se. Neurotic individuals might have been more sensible to this arousing context, leading to more energy expenditure. In terms of perceived personality traits, extraversion and openness were embedded in the general impression G and, therefore, were associated with impulsivity. This association seems to be consistent with a description of extrovert people as energetic individuals [Costa and McCrae 1992]. However, in our task, it was misleading: extrovert coaches performed more expanded movements, not more impulsive movements. Perceived agreeableness was positively correlated with computed spatial extent and perceived smoothness. Although we did not form an hypothesis regarding this dimension, this result is interesting because agreeableness has been observed to be related to individuals engaging in smooth interaction with others [Graziano et al. 2007]. From this last set of results, we can draw two conclusions. First, information regarding personality traits are conveyed by coaches' kinematics computed as movement qualities, but observers are not able to accurately identify them: more information might be needed to reduce the ambiguity of the signals. Second, two personality traits might be advantageously expressed by a virtual coach: extraversion embedded in the general impression driven by movement impulsivity and agreeableness, which is strongly associated with perceived smoothness. However, additional analyses are required to identify what kinematic patterns drive this perceived smoothness.

Common to analyses 2 and 3 is the fact that "residual" variables (i.e., perceived smoothness, spatial extent, emotional valence, motivation and agreeableness) represent a very small part (although significant) of the overall variance and should be consider with caution. Future studies could investigate the reproducibility of these perceptual structures within similar circumstances.

Overall, these analyses revealed that information was conveyed but without accuracy, a sign of high ambiguity. Whilst emotional activation seemed partially accurate via the accurate perception of energy/impulsivity movement qualities, the other self-reported dimensions were not perceived directly perhaps because of their more subtle embodiment (i.e., lower correlations with computed movement qualities). To investigate in a more global manner the overall quantity of information conveyed, canonical correlations could be used in future research. Such a method requires very large samples (i.e., about 20 observations per variables in the model) and thus need more participants.

4.6 Future directions

The nature of our perceptual protocol, where observers were passively watching movement sequences, is a limitation. As future users will actively perform the movement following the virtual coach, their perception of emotion and personality traits might be different. An interesting question in our future experimental setup would be to reproduce the perceptual evaluation of this study after performing an interactive session with the virtual coach.

The presentation of movement sequences via a neutralized 3D manikin also raises several questions. In our analyses, although accuracy is low for most dimensions, we noted that social information was conveyed through movement qualities and social perception was related to movement qualities. This means that observers perceived information but were not able to disambiguate it probably as a consequence of the impoverished stimuli. Additional cues such as physical appearance and facial expressions would probably interact with the perception of emotion and personality traits. A possible future work would be to replicate this study by presenting a video of real coaches performing the motion sequence. This would enable us to obtain some knowledge regarding the complementary role of kinematics when other communicative modalities are available as performed in [Naumann et al. 2009]. The relative contributions of the different body parts to the social perceptions would be an additional interesting research question.

Another aspect to be considered is the asexual aspect of the 3D manikin: the virtual coach will be sexualized to fit as much as possible a real coach condition. The additional gender information might influence the inference made by observers. Again, replicating this study by presenting a video of real coaches would provide some information regarding the possible influence of gender. The proportions of the manikin might also be changed to investigate how anthropomorphism impact impression formations. A last aspect, which impaired the ability of observers to perceive emotions and personality traits through movement qualities, is the spontaneous nature of our corpus: not intended to be explicitly communicated, social information leaks through kinematics. While accuracy is reduced, this methodological choice enabled us to collect more ecological data. This will ensure the kinematics patterns of our virtual coach are realistic and are not stereotyped.

The specific use of learned fitness movements has implications regarding the existing literature on movement qualities. The study of everyday movements such as walking or drinking induces the collect of more automatic motions perhaps less subject to context (i.e., emotions) and stylistic (i.e., personality) variations. However, performing a movement sequence predefined in its form might have induced another form of rigidity and limit the kinematic variability. An interesting future research project would be to characterize these sources of rigidity and study how they interplay with other sources of variabilities (e.g., emotions).

Overall, this paper provides some insights for the design of an interactive virtual fitness coach. While varying movement impulsivity will drive most of the expressiveness attributions of the coach, motivation and agreeableness are the other two interesting and expressive variables to play with to adapt our coach's movement qualities to the user. Using modern methods for the modeling of stylized movements [Tilmanne and Dutoit 2012], future studies will enable us to study the influence of these various attributes conveyed through movement qualities on energy expenditure and engagement in the fitness task. The relevance of studying the communication of these various social attributes (i.e., emotions and personality) was based on the idea that a virtual coach conveying positive expressive attributes would be more enjoyable and as a consequence foster home exercise. This assumption should be investigated in future researches based on longitudinal experiments of virtual coach practicing.

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Online Appendix to: Emotion and personality perception through full-body movement qualities: a sport coach case study

XX, xx

A. MOVEMENT QUALITIES COMPUTATION

Times series - Descriptive	**Equation**
Impulsiveness (Equation 1): Time effort can be determined as the net acceleration at the body parts over time. Large values of net acceleration indicate sudden movements characterized by a high impulsiveness.	$I_{member} = \frac{\lvert V(t_i) - V(t_{i-1})\rvert}{t_i - t_{i-1}}$ $Vi(t)$, velocity of the member.
Energy (Equation 2): Weight effort can be determined as energy at each instant (t) over time. m_{member} is the approximation of the mass of each member according to the Winter table (Winter 2004). Large values of energy indicate strong movements.	$E_{member} = \frac{1}{2} m * Vi(t)^2$ $Vi(t)$, velocity of the member.
Directness (Equation 3): Space effort is computed as the inner product of chest and member displacement (i.e., right hand, left hand, right foot, left foot) trajectories. Direct movements are thus usually characterized by a small number of peaks.	$D_{member} = \overrightarrow{V_{chest}} * \overrightarrow{V_{member}} = (V_{chest\,X} \quad V_{chest\,y} \quad V_{chest\,z}) * \begin{pmatrix} V_{member\,X} \\ V_{member\,Y} \\ V_{member\,Z} \end{pmatrix}$ $\overrightarrow{V_{chest}} * \overrightarrow{V_{member}}$, tangents to chest and member positions.
Smoothness (Equation 4): Flow effort is determined as the 3D curvature for each segment for each time. The curvature is a rapport between velocity and acceleration. Computation of curvature gives larger values for smooth movement and high values for jerky movements. A negative sign is added to correspond to the label "smoothness": high value correspond to smooth movements.	$S_{member} = -\frac{\sqrt{(v_{xi} * a_{yi} - v_{yi} * a_{xi})^2 + (v_{zi} * a_{xi} - v_{xi} * a_{zi})^2 + (v_{yi} * a_{zi} - v_{zi} * a_{yi}}}{(v_{xi^2} + v_{yi^2} + v_{zi^2})^{\frac{3}{2}}}$ v_{xi} *and* a_{xi} indicate the first and second derivatives of the member position at frame i, respectively.
Spatial Extent (Equation 5): Shape Qualities describe the way the body is changing toward space. Spatial extent is associated to the position of each segment according to the center of mass at each time. Values of Expansiveness are close to zero for dense movements and are high for expanded movements.	$Ex = ¾ * \Pi * DI_x * DI_y * DI_z$ $DIx = \frac{1}{n}\sum_{m=1}^{n}\sqrt{(x_{mi} - x_{ci})^2}$ D $Iy = \frac{1}{n}\sum_{m=1}^{n}\sqrt{(y_{mi} - y_{ci})^2}$ $DIz = \frac{1}{n}\sum_{m=1}^{n}\sqrt{(z_{mi} - z_{ci})^2}$ DIx, DIy, DIz are the sum of distances between the mass center coordinate (x_{ci}, y_{ci}, z_{ci}) and the n-th member coordinate (x_{mi}, y_{mi}, z_{mi}) at frame i.

Adapted from [Piana et al 2013, Kapadia et al 2013, Samadani et al 2013, Chen et al 2011].

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B. FRENCH VERSION OF THE EVALUATED DIMENSIONS

Movement qualities		Left anchor[a]		Right anchor[b]	
English	French	English	French	English	French
Smoothness	Fluidité	Abrupt	Abrupt	Smooth	Fluide
Directness	Directivité	Indirect	Indirect	Direct	Direct
Energy	Energie	Limp	Mou	Energetic	Energique
Impulsivity	Impulsivité	Restrained	Retenu	Impulsive	Impulsif
Spatial extension	Extension	Restricted	Restreint	Vast	Etendu
Emotion		**Left anchor[a]**		**Right anchor[b]**	
English	French	English	French	English	French
Valence	Valence	Negative	Emotion	Positive emotion	Emotion
Intensity	Intensité	Low intensity	Faible	Strong intensity	Forte intensité
Dominance	Dominance	Subdued	Soumise	Dominant	Dominante
Motivation	Motivation	Without	Sans	Strongly	Très motivé
Stress	Stress	Relaxed	Pas stressé	Stressed	Très stressé
Personality		**Left anchor[a]**		**Right anchor[b]**	
English	French	English	French	English	French
Extraversion	Extraverti	Introverted	Introverti	Extroverted	Extraverti
Openness	Aventureux	Humdrum	Routinier	Adventurous	Aventureux
Neuroticism	*Stable*	*Neurotic*	*Névrosé*	*Stable emotionally*	*Stable*
Conscientiousness	Consciencieux	Careless	Négligent	Conscientious	Consciencieux
Agreeableness	Chaleureux	Disagreeable	Désagréable	Warm	Chaleureux

[a] Score = 1

[b] Score = 10

Italic scales inverted from French to English

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C. MULTITRAIT-MULTIMETHOD MATRIX

	Sm M1	En M1	Im M1	Sp M1	Va M1	In M1	Do M1	Mo M1	Ex M1	Op M1	Ne M1	Ag M1	Sm M2	En M2	Im M2	Sp M2	Va M2	In M2	Do M2	Mo M2	Ex M2	Op M2	Ne M2	Ag M2
Smoothness M1	(0.89)																							
Energy M1	.678**	(0.96)																						
Impulsivity M1	.598**	.962**	(0.95)																					
Spatial Extent M1	.713**	.812**	.836**	(0.95)																				
Valence M1	.870**	.870**	.845**	.872**	(0.95)																			
Intensity M1	.706**	.953**	.948**	.864**	.926**	(0.95)																		
Dominance M1	.614**	.935**	.953**	.727**	.847**	.928**	(0.93)																	
Motivation M1	.718**	.907**	.929**	.858**	.939**	.972**	.925**	(0.95)																
Extraversion M1	.683**	.926**	.950**	.770**	.891**	.948**	.973**	.948**	(0.93)															
Openness M1	.650**	.907**	.954**	.794**	.886**	.941**	.961**	.962**	.980**	(0.95)														
Neuroticism M1	.856**	.806**	.760**	.755**	.925**	.841**	.798**	.826**	.836**	.823**	(0.87)													
Agreeableness M1	.852**	.842**	.828**	.810**	.980**	.891**	.844**	.928**	.887**	.891**	.921**	(0.93)												
Smoothness M2	.828**	.479*	.425*	.499*	.679**	.497*	.421*	.512*	.475*	.427*	.670**	.684**	(0.81)											
Energy M2	.605**	.949**	.927**	.763**	.812**	.933**	.894**	.863**	.900**	.877**	.755**	.766**	.422*	(0.86)										
Impulsivity M2	.595**	.943**	.928**	.779**	.806**	.921**	.886**	.859**	.895**	.868**	.727**	.751**	.435*	.985**	(0.86)									
Spatial Extent M2	.523*	.746**	.763**	.901**	.733**	.816**	.632**	.772**	.684**	.700**	.586**	.640**	0.300	.785**	.805**	(0.90)								
Valence M2	.725**	.807**	.724**	.585**	.805**	.809**	.763**	.752**	.796**	.735**	.803**	.797**	.663**	.787**	.755**	.477*	(0.87)							
Intensity M2	.504*	.870**	.905**	.704**	.775**	.883**	.901**	.871**	.892**	.912**	.720**	.768**	0.342	.903**	.888**	.702**	.710**	(0.91)						
Dominance M2	.505*	.787**	.707**	.443*	.636**	.705**	.736**	.619**	.716**	.639**	.633**	.627**	.528**	.757**	.754**	0.360	.905**	.664**	(0.88)					
Motivation M2	.664**	.871**	.842**	.732**	.852**	.872**	.837**	.869**	.852**	.857**	.730**	.836**	.477*	.851**	.839**	.659**	.836**	.877**	.753**	(0.83)				
Extraversion M2	.726**	.918**	.895**	.790**	.889**	.910**	.868**	.888**	.888**	.871**	.777**	.865**	.576**	.868**	.888**	.718**	.801**	.776**	.763**	.859**	(0.92)			
Openness M2	.697**	.749**	.781**	.747**	.859**	.810**	.780**	.859**	.823**	.844**	.763**	.851**	.577**	.745**	.781**	.686**	.644**	.767**	.530**	.796**	.880**	(0.88)		
Neuroticism M2	0.271	0.320	0.251	0.025	0.254	0.197	0.332	0.219	0.281	0.251	0.243	0.315	.451*	0.317	0.355	-0.008	0.370	0.300	.487*	0.385	0.405	.437*	(-0.16)	
Agreeableness M2	.661**	.668**	.645**	.518*	.781**	.701**	.730**	.777**	.751**	.764**	.749**	.830**	.601**	.613**	.633**	0.400	.671**	.688**	.563**	.753**	.723**	.847**	.607**	(0.84)

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