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# Preference for Point-Light Human Biological Motion in Newborns: Contribution of Translational Displacement

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# Preference for Point-Light Human Biological Motion in Newborns: Contribution of Translational Displacement

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In human newborns, spontaneous visual preference for biological motion is reported to occur at birth, but the factors underpinning this preference are still in debate. Using a standard visual preferential looking paradigm, 4 experiments were carried out in 3-day-old human newborns to assess the influence of translational displacement on perception of human locomotion. Experiment 1 shows that human newborns prefer a point-light walker display representing human locomotion as if on a treadmill over random motion. However, no preference for biological movement is observed in Experiment 2 when both biological and random motion displays are presented with translational displacement. Experiments 3 and 4 show that newborns exhibit preference for translated biological motion (Experiment 3) and random motion (Experiment 4) displays over the same configurations moving without translation. These findings reveal that human newborns have a preference for the translational component of movement independently of the presence of biological kinematics. The outcome suggests that translation constitutes the first step in development of visual preference for biological motion.

*Keywords:* visual perception, infancy, biological movement, translational displacement

Visual processing of biological motion (BM) produced by living organisms is of immense value for a variety of daily life activities, in particular, for successful social interaction and nonverbal communication (see Pavlova, 2012, for review; Saygin, Cook, & Blakemore, 2010). The human visual system is highly sensitive to motion produced by living beings, even when this motion is represented only by some dots of light attached to the major joints of an invisible actor (Johansson, 1973). The mature visual system of adults needs only very brief exposure (100 ms of stimulus duration) to differentiate between point-light displays depicting human actions such as walking or jogging (Johansson, 1976).

Behavioral studies (Bertenthal, 1996; Bertenthal & Campos, 1987; Fox & McDaniel, 1982; Méary, Kitromilides, Mazens, Graff, & Gentaz, 2007; Ruff, 1982) and analysis of brain activity (Hirai & Hiraki, 2005; Lloyd-Fox, Blasi, Everdell, Elwell, & Johnson, 2011; Reid, Hoehl, Landt, & Striano, 2008) show that visual sensitivity to BM emerges early in human development (see Pavlova, 2012; Simion, Di Giorgio, Leo, & Bardi, 2011, for review). By 4–6 months of age, infants exhibit a preference for a canonical point-light human walker over an inverted walker or random motion (Fox & McDaniel, 1982). By 3–5 months of age, infants discriminate a human point-light walker from similar dis-

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plays with scrambled spatial relationships (Bertenthal, Proffitt, & Kramer, 1987) or perturbed local rigidity (Bertenthal, Proffitt, Spetner, & Thomas, 1985) between moving dots. Most recently, it was reported that visual sensitivity to BM might be present at birth. The first evidence was provided by Vallortigara et al. in their investigation of newly hatched chicks (Vallortigara & Regolin, 2006; Vallortigara, Regolin, & Marconato, 2005) and later confirmed in human newborns (Bardi, Regolin, & Simion, 2011; Simion, Regolin, & Bulf, 2008). Two-day-old newborns show a visual preference for an upright point-light hen over random motion and an upside-down display (Simion et al., 2008), but no preference occurred between biological and spatially scrambled displays that consists of the same amount of absolute motion but lacks an implicit body structure (Bardi et al., 2011). It appears therefore, that preference of newborns to canonical BM consisting of a hierarchy of pendular motions of the dots placed on the main joints is limited.

One of the restrictions of previous studies is that they did not examine the impact of the translational component of BM. Instead they concentrate on BM pattern moving as if on a treadmill with no net translation. Translational component of BM refers to the horizontal displacement associated with BM: Real locomotion is always associated with a spatial displacement (to the left, right, forward, or backward). Although BM with horizontal translational component is rarely used in experiments with infants (e.g., Reid, Hoehl, & Striano, 2006), it appears obvious that translation is an intrinsic ecologically valid component of BM (Proffitt, Bertenthal, & Roberts, 1984). In accordance with this, translation is reported to beneficially affect BM perception in adults and makes point-light displays more natural and, therefore, easily recognizable (Johansson, 1976; Proffitt, 1983). In the same vein, Pavlova and Sokolov (2003) reported that prior information about display inversion facilitates recognition of upside-down point-light BM displays when it is complemented by inserting either a static or a moving background element that leads to an impression of translation.

It is known that visual competencies of human infants improve very fast during the first weeks after birth (see Braddick & Atkinson, 2011, for a recent review), and sensitivity to translating motion appears earlier than to other types of motion such as rotation (e.g., Eizenman & Bertenthal, 1998; Ruff, 1982). The present work examines for the first time the impact of translational displacement on the spontaneous visual preference for BM in human newborns. Experiment 1 extends the previous studies that used a point-light hen (Bardi et al., 2011; Simion et al., 2008) and shows that newborns exhibit visual preference for human locomotion (a point-light walker over random motion) when presented without translation. Experiment 2 examines the role of translational displacement in visual preference by comparing visual preference to biological and random motion displays both presented with a translational displacement ("translating walker" vs. "translating random" conditions). Finally, Experiments 3 and 4 investigate whether visual preference occurred for translational movement independently of biological kinematics ("walker with translation" vs. "walker without translation" conditions in Experiment 3, and "random motion with translation" vs. "random motion without translation" conditions in Experiment 4).

## Experiment 1: Point-Light Walker Versus Point-Light Random Motions

Previous studies indicating a predisposition for biological movements at birth in human newborns used animations representing a point-light walking hen. The use of such displays has some advantages for studying visual preference in newborns, among which is excluding potential previous visual experience with stimuli (Simion et al., 2008). However, the visual preference for a walking human figure has previously never been demonstrated in human newborns and has been observed only in infants older than 4 months (Fox & McDaniel, 1982). Experiment 1 examined whether human newborns exhibit preference for human point-light biological motion over random motion, with no translational displacement in either condition.

### Method

**Participants.** Fourteen full-term newborns (seven girls, seven boys) aged between 72 and 100 hr participated. They were tested in the "Clinique Mutualiste" hospital nursery in Grenoble, France, just before or after standard medical examinations. Participation in the study was proposed to all families on a voluntary basis. Given that clinic was not public, all families had rather high (or privileged) socioeconomic status. Most families had European (85%) or North African origin (10%), and all reported speaking French at home. Infants were tested with informed written consent of their parents. Data of two participants were removed from consequent data processing because one cried and one slept during a substantial part of the experiment. Data of 12 newborns (seven girls, five boys, *M* age = 89.1 hr; *SD* = 8.6 hr) were further processed. The present study was approved by a local ethical committee of University Pierre Mendès of Grenoble and CNRS (LPNC UMR 5105).

**Stimuli.** Animated sequences were built with Matlab using (x, y) coordinates provided by a point-light actions corpus (available at http://astro.temple.edu/~tshipley/mocap/dotMovie.html; see Shipley & Brumberg, 2005, for more details). Each display consisted of 60 frames of motion with 25 ms each resulting in duration of 1.5 s. Two visual patterns were compared. They consisted of sets of nine white dots (97 candela/m$^2$, Ø = 0.6 cm, which corresponds to a visual angle of 0.8° at a viewing distance of 45 cm) moving against a dark background (0.14 candela/m$^2$). As described by Brown and Yamamoto (1986), several authors evaluate the visual acuity in newborns near 0.75 cycle/degree (i.e., Miranda, 1970) that corresponds to 40 angle of arc minutes or 0.66 degrees in visual angle. Therefore each dot constituting the point-light display has a diameter superior to what is visible at birth.

Point-light walker motion consisted of a point-light sequence representing a man (nine dots located on the main joints: left shoulder, left elbow, left wrist, left hip, knees, ankles and the head) walking as if on a treadmill (video clips are available at https://bv.univ-poitiers.fr/access/content/user/cildei/stimuli%20bébé/). The starting position of each dot was situated in the center of the screen. The set of dots occupied a window of 5 cm (H) × 14 cm (V), which corresponds to the actual visual angle 6.4° (H) × 17.8° (V) at a viewing distance of 45 cm. The trajectory and kinematics of each dot of this biological stimulus corresponded to the actual displacement of the joints of a walking man with a mean velocity of 12 cm/s (15.29°/s). Random point-light motion consisted of nine light dots randomly distributed in the center of the screen in a 6.4° (H) × 17.8° (V) window. Each dot of the random motion display corresponds to a dot representing a joint of the point-light walker. The position and velocity of dots were assigned on a frame-by-frame basis. More specifically, we calculated for each dot of the BM the differences between two frames for both X $[(x + 1) - x]$ and Y$[(y + 1) - y]$ positions. These differences were randomized in order to obtain a random tangential velocity in X and Y, respectively. This procedure disrupts both global and local coordination of BM but preserves the mean tangential velocity of BM. X and Y differences obtained for each frame were then implemented from starting random positions. The starting X position was chosen randomly between 16.5° and 22.9° of horizontal visual angle and the Y starting position was chosen randomly between 8.9° and 26.7° of vertical visual angle at a viewing distance of 45 cm.

**Apparatus and procedure.** The conditions were similar to those used in Méary et al. (2007). The babies were placed in an adapted rigid seat fixed on a trolley. Two cushions were positioned on each side of the baby's head to attend 40° inclination. Once the baby was comfortably positioned, the apparatus was placed in front of a visual display so that the distance between the newborn's gaze and the screen was about 45 cm. The display was composed of two identical LCD screens (17-in., 32.5 cm × 24.5 cm, spatial resolution = 1280 × 1024 pixels; sampling frequency = 85 Hz) and a digital video camera placed in front of the eyes of the newborns recording the newborn's reaction (sampling frequency = 25 Hz). The camera was placed between the two screens in a gap of 5 cm. The whole apparatus was covered with a black cardboard in order to hide the screen's borders, the camera and the experimenter from newborn's sight (see Figure 1).

One sequence of motion comprised 1 min 15 s of uninterrupted motion. During this time sequence, both visual stimuli were presented 25 cycles on each screen. After 25 cycles, each stimulus changed sides in such way that each was presented half the time to the right and half the time to the left of the participant. The starting position of the stimuli (left or right) was counterbalanced to control for possible position related biases. The different cycles of these stimuli were displayed in a loop in order to appear continuously without any break.

**Data analysis.** We compared the looking time (in seconds) of newborns according to the nature of the stimulus, namely, a point-light walker and point-light random motion. Two coders, blind with respect to the experimental manipulations, had to classify the newborn's behavior according to three categories (gaze directed to the right or the left from midline of the screen, and gaze directed elsewhere). This coding was made on a frame-by-frame basis. Each coder's judgment (right, left or elsewhere) was associated with stimuli in each condition. Data have been conserved only when both observers agreed on the gaze direction (perfect reliability). About 3% of the data have been removed due to disagreement between the coders. We checked that all newborns looked at the stimuli at least 50% of time and had at least 15% of the remaining time spent looking at each screen. As our data were not normally distributed (Kolmogorov-Smirnov adjustment test indicates that observed data cannot be adjusted by normal Gaussian distribution), nonparametric statistical tests (Wilcoxon comparison) with the type of movement as within-subject factor was used to assess visual preference. For each case, effect size was indicated with r value.

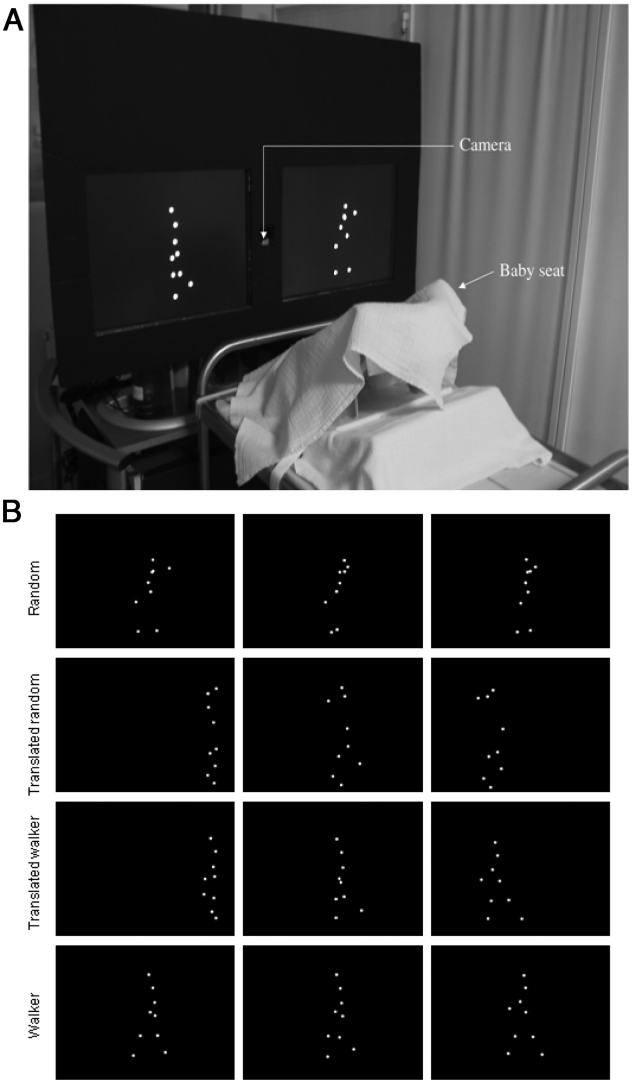

*Figure 1.* A. Experimental setup. Newborns were seated on a rigid seat fixed and placed in front of two screens where the displays were simultaneously presented (in this illustration, biological movement is on the left and random motion is on the right). A camera is placed between the screens. B. Three sample frames taken from the animation sequences used in the study: random motion without translation (upper frames), random motion with translation, a point-light walker with translation, a point-light walker without translation (lower frames). Video clips are available at https://bv.univ-poitiers.fr/access/content/user/cildei/stimuli%20bébé/

## Results and Discussion

As can been seen in Figure 2A, newborns looked longer at a point-light walker than at point-light random motion ($Z = 1.96$; $p < .05$, $r = .57$; median = 39.8 s; median = 31.5 s, for point-light walker and point-light random motion, respectively). This holds true for eight out of 12 newborns and four infants did not show any preference for biological over random motion. These results ex-

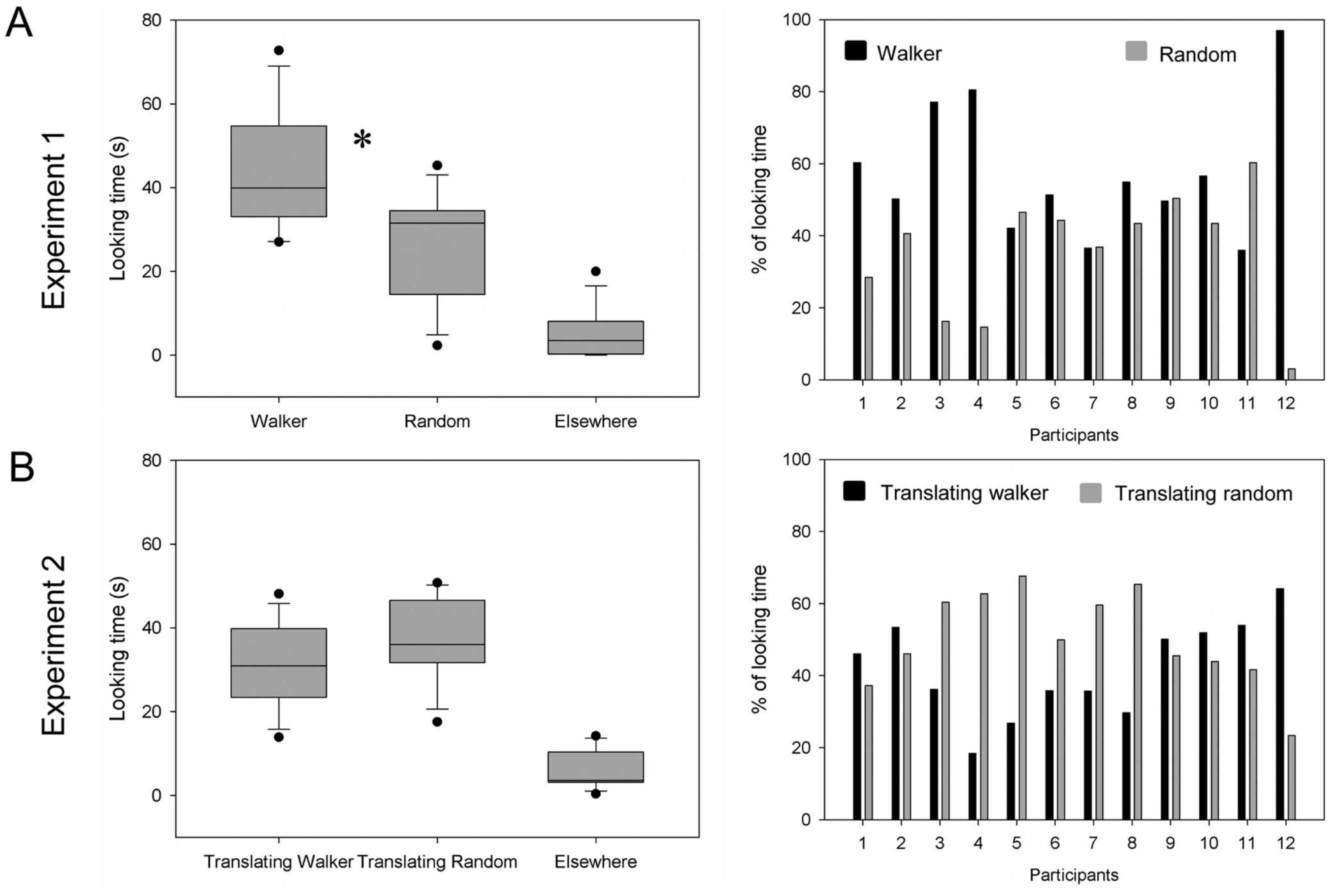

*Figure 2.* On the left, boxes represent distributions of looking time for Experiment 1 (A) and Experiment 2 (B). Horizontal bold lines designate medians, error bars represent quartile, and black dots represent outliers. Asterisks indicate significant differences estimated by Wilcoxon comparisons. On the right, histograms show the individual data for each experiment. Each experiment has been made with a new group of newborns.

tend previous findings (Simion et al., 2008) by showing that human newborns prefer BM represented by a human walker over random motion with no translational displacement in both conditions. This experiment was necessary as a first step for our further study that was aimed at clarification of the potential role of translational displacement in BM perception in human newborns.

## Experiment 2: Translating Point-Light Walker Versus Translating Point-Light Random Motions

Experiment 2 investigated visual preference of human newborns for human point-light biological motion over random motion displays both presented with translational displacement.

### Method

Fourteen human full-term newborns (seven girls, seven boys) aged between 70 and 105 hr participated in this experiment. The data of two babies were removed because of computer error in data collection. The data of six girls, six boys ($M = 87.3$ hr, $SD = 10.6$ hr) were submitted to further processing. The same apparatus and procedure as in Experiment 1 (see above) were used, and the stimuli were generated in the same way. The present experiment compared a point-light translating walker motion with a point-light translating random motion.

Point-light walker motion with translation consisted of a point-light sequence representing a man (nine points of lights located on the main joints: left shoulder, left elbow, left wrist, left hip, knees, ankles and the head) walking three steps from the right to the left in the frontoparallel plane. The starting position of each dot was on the right of the screen between 33.1° and 39.5° of the horizontal (H) and between 8.9° and 26.7° of the vertical (V) visual angle at a viewing distance of 45 cm. As for the point-light walker motion, the set of dots was spread in a window of 5 cm (H) × 14 cm (V), which corresponds to the actual visual angle 6.4° (H) × 17.8° (V) at a viewing distance of 45 cm. The distance covered by the stimulus from right to left was 18 cm, i.e., 22.92° of visual angle at a viewing distance of 45 cm. The trajectory and kinematics of each dot was identical as the one used for the point-light walker stimulus. The mean velocity of displacement was 15.29° of visual angle/second. This corresponds with the velocity allowing smooth-pursuit eye movements of a moving target in human newborns (Bloch & Carchon, 1992; Dayton et al., 1964; Kremenitzer, Vaughan, Kurtzberg, & Dowling, 1979; Lengyel, Weinacht, Charlier, & Gottlob, 1998). Moreover, this horizontal displacement corresponds with the visual preference for static horizontal pattern observed in human newborns (Slater & Sykes, 1977). The different cycles of this stimulus were displayed in a loop in order to appear continuously. In each loop, the stimulus appeared on the right of the screen and moves three steps toward the left following an imaginary horizontal line.

Point-light translating random motion was placed in the same horizontal and vertical window as the translating point-light walker stimulus (on the right of the screen). As in Experiment 1, the movement of a particular dot corresponded to the tangential velocity of the trajectory of dots on the joints of the biological stimulus but was displayed in a random order and at different random initial (x, y) coordinates. Moreover, the dots moves with a global translation, from right to left similarly to the translating point-light walker motion. As in Experiment 1, both stimuli differed only in motion kinematics.

## Results and Discussion

The findings (Figure 2B) indicate that looking time for a translating point-light walker does not differ from looking time for translating point-light random motion ($Z = 1.09$; $p = .27$, $r = .32$; $Mdn = 30.8$ s and $Mdn = 36$ s for translating biological and translating random motion, respectively). Six newborns displayed a preference for biological motion, whereas the others looked preferentially at random motion.

The present experiment suggests that human newborns are not specifically attracted by BM in the presence of another similar configuration with translation. This is intriguing and suggests that translational displacement could be “an attractor” for the human visual system at birth.

# Experiment 3: Translating Point-Light Walker Versus Point-Light Walker Motions

This experiment was aimed at evaluating the influence of translational displacement in visual preference for BM by assessing preferential looking at a point-light walker with horizontal translation over the same configuration without translational displacement.

## Method

Fourteen human full term newborns (seven girls, seven boys) aged between 75 and 102 hr ($M = 85.6$ hr, $SD = 5.7$ hr) participated in this experiment. One baby was excluded because the two coders did not reach consensus in classifying its behavior during the experiment. Thirteen babies were submitted to further analysis (seven girls, six boys, $M = 85.3$ hr, $SD = 5.2$ hr). We used the same apparatus, procedure and stimuli that were previously described in order to compare directly a point-light walker with translation that was used in Experiment 2 with point-light walker motion without translation used in Experiment 1. The only difference between these two visual patterns lay in the presence of translational displacement.

## Results and Discussion

Results (Figure 3A) indicated that human newborns preferred looking at a point-light walker with translation than at a point-light walker without translation ($Z = 2.90$; $p < .001$, $r = .80$; $Mdn = 50.6$ s and $Mdn = 17.7$ s for walker with and without translation, respectively). This holds true for 10 out of 13 newborns and three infants did not show any preference for the translating over non translating walker. This finding shows that human newborns prefer looking at BM represented by a human walker with translation rather than the same configuration without translation. Therefore, the findings demonstrate that translational displacement affects visual preference for point-light BM in newborns.

# Experiment 4: Translating Point-Light Random Versus Point-Light Random Motions

This experiment addresses the issue of whether the translational displacement is sufficient to obtain a preference between nonbiological point-light stimuli. With this purpose in mind, newborns were presented with point-light random motion displays with and without translational displacement.

## Method

Fourteen human full-term newborns (seven girls, seven boys) aged between 78 and 100 hr participated in this experiment. Two of them were excluded because they presented a lot of very short fixations that were difficult to categorize. The data of five girls and seven boys were submitted to further analysis ($M = 88.58$ hr, $SD = 6.81$ hr). We used the same apparatus, procedure and stimuli that were previously described in order to compare directly a point-light random motion with translation that was used in Experiment 2 with point-light random motion without translation used in Experiment 1. As in Experiment 3, the only difference between these two visual patterns was in the presence of translational displacement.

## Results and Discussion

The findings (Figure 3B) indicate that human newborns preferred looking at point-light random motion with translation than at point-light random motion without translation ($Z = 2.04$; $p < .05$, $r = .61$; $Mdn = 41.9$ s and $Mdn = 23.3$ s for translating random and random motions, respectively). This was true for 10 out of 12 newborns. These results clearly show that human newborns are attracted by translational displacement independently of biological and nonbiological kinematics.

# General Discussion

The visual sensitivity to BM is believed to emerge early in human development. Previous work, however, was focused on the role of dynamical and configural properties of point-light displays representing different types of locomotion, and overlooked the influence of translational displacement. The first experiment of the present study shows that without horizontal translational displacement human newborns exhibit a preference for a human point-light walker over random motion. This outcome largely agrees with the previous findings obtained with nonhuman species (Vallortigara et al., 2005) and extends to human walking the findings obtained in human newborns with a display representing nonhuman BM of a point-light walking hen (Simion et al., 2008). The present data, however, appear to contradict the findings by Fox and McDaniel

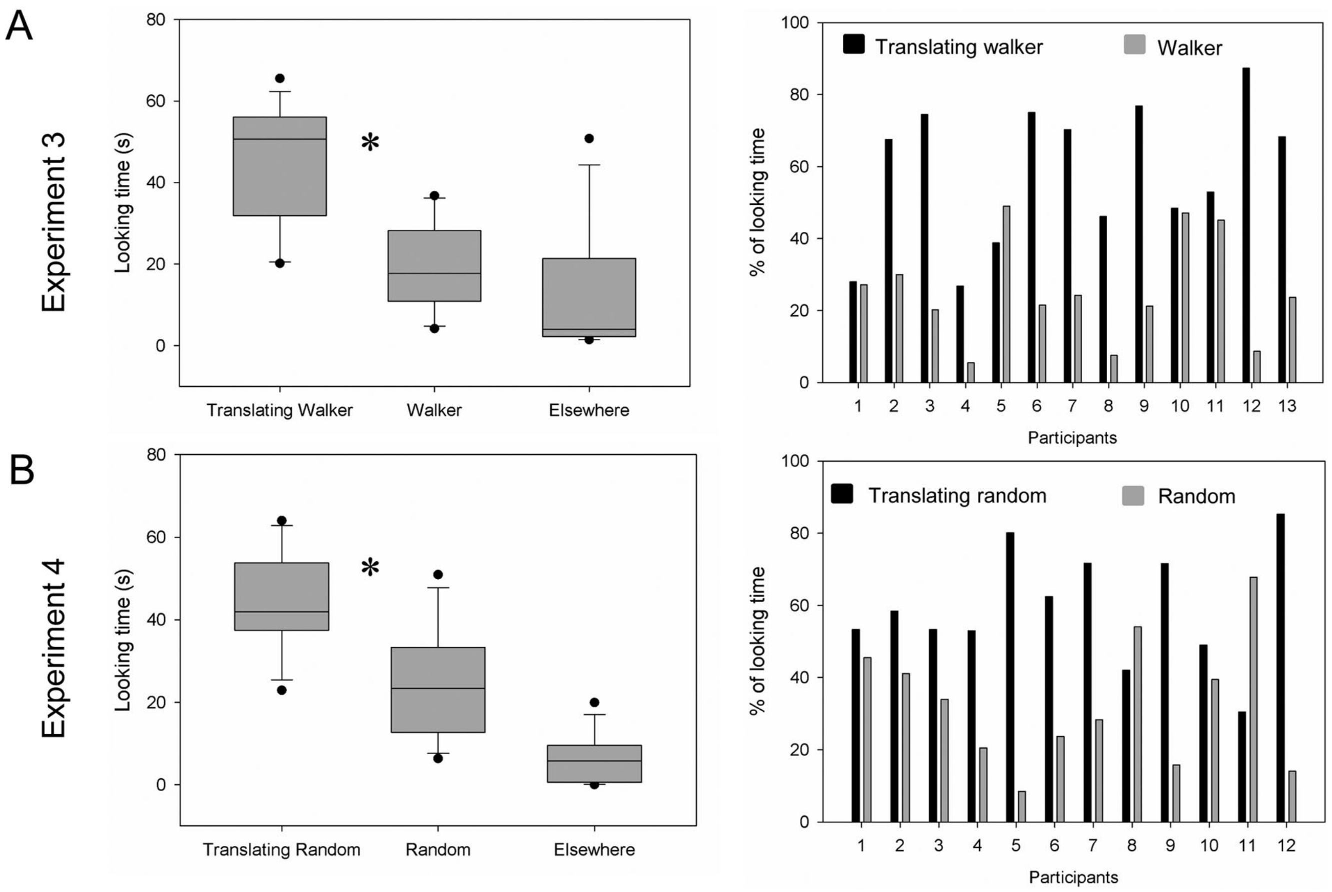

*Figure 3.* On the left, boxes represent distributions of looking time for Experiment 3 (A) and Experiment 4 (B). Horizontal bold lines designate medians, error bars represent quartile, and black dots represent outliers. Asterisks indicate significant differences estimated by Wilcoxon comparisons. On the right, histograms show the individual data for each experiment. Each experiment has been made with a new group of newborns.

(1982), which have shown that only infants older than 4 months exhibit visual preference for a point-light human walker over dynamic noise. Here we demonstrate that 3-day-old human newborns exhibit preference for point-light human gait. This discrepancy could be accounted for by several methodological differences. First, in our experiment, walking patterns were used, whereas Fox and MacDaniel (1982) investigated the visual preference for displays representing running motor activity. Given particular importance of human locomotion, one can assume that sensitivity to human walking emerges earlier than other types of motion (e.g., dancing). Second, in our experiment, presentation time (about 1 min 15 s) was longer than in the study by Fox and McDaniel (about 15 s). As suggested of Simion et al. (2008), short trial duration could affect occurrence of visual preference. Further experiments should address these methodological issues that might explain the differences between our findings and those by Fox and MacDaniel (1982).

The second experiment shows that with translational displacement, newborns do not exhibit any preference for a point-light walker over random motion. This is an intriguing finding that suggests that translational component affects visual preferences of human newborns to point-light displays. This assumption was confirmed in Experiments 3 and 4, which showed that point-light displays with translation were preferred over equivalent displays with no net translation.

Taken together, these findings shed light on the putative role of translational component in newborns' visual BM perception. They extend previous findings (Bardi et al., 2011; Chang & Troje, 2008, 2009) by showing that not only local and global components of motion but also translational displacement contribute to visual processing of point-light biological motion. Actually, when translational displacement is present, occurrence of local and global coordination between dots on the joints, which is sufficient for extracting an invariant body structure in healthy adults, does not elicit any visual preference in comparison with random display (Experiment 2). As proposed a long time ago by Gestalt psychology (Köhler, 1945/1964), the common fate principle might account for the visual sensitivity in newborns. At the brain level it was shown that visual evoked potentials in infants are largest when they observe a group of dots that move in the same direction (Gilmore, Hou, Pettet, & Norcia, 2007). In accordance with this view, a global horizontal translational displacement may help to reveal a whole cloud of dots that can be interpreted as a global shape even if it does not correspond to a recognizable human figure. Therefore, both point-light biological and random motion displays with translational displacement may be perceived as a whole. This could explain the lack of preference observed in the present study between a point-light walker and a point-light random motion with translation. This is also in accord with the "minimum principle" (Cutting & Proffitt, 1982), which proposes that the visual system tries to minimize plausible interpretations of visual stimuli.

Vallortigara et al. (2005) hypothesized that preference of newborns is not triggered by the specific biological motion of a species but rather by a mixture of rigid motion and nonrigid motion which is specific for movements of most vertebrates (see also Vallortigara, 2012). Thus, it seems likely that a translational component of movement provides an element of rigidity of the whole configuration which, together with nonrigid movements associated with local random motion, makes the pattern "biological."

In healthy adults, the visual sensitivity to BM with translation is reported to be higher than to the translation of a point-light rectangle embedded in a random motion mask (Hiris, 2007). This indicates how translational displacement is important for veridical BM's perception. For the mature visual system not only translation matters but also specific hierarchy of pendular motions underlying biological form. Recent data in human newborns suggest that the presence of invariant human structure *per se* cannot completely account for the visual preference for BM at birth: BM with no net translation is preferred over structured nonbiological motion (a rotating static frame from a sequence depicting a point-light hen), but not over a spatially scrambled display that consists of the same amount of absolute motion but lacks an implicit body structure (Bardi et al., 2011).

At first glance, the present data contradict the findings in 3-months-old infants who were habituated longer to a canonical point-light walker than to scrambled display independent of translation component (Bertenthal, Proffitt, Kramer, & Spetner, 1987). This indicates that the role of translational component in BM perception is different in newborns and older infants. It appears that for older infants translation does not play a crucial role in processing of biological motion, but for newborns it does. Although this assumption should be assessed in future experiments, it suggests that development of BM perception is not linear.

Finally, visual preference for translational movement found in the present study might provide an explanation for the visual preference for BM without translation over random motion (Experiment 1). Actually, contrary to random motions, it is known that BM without translational displacement may elicit a vivid impression of translational motion. In accordance with this, adults are able to infer direction of a point-light human movement even if there is no actual translation (e.g., Bidet-Ildei, Chauvin, & Coello, 2010; Cutting, Moore, & Morrison, 1988; Pavlova, Krageloh-Mann, Birbaumer, & Sokolov, 2002; Saygin et al., 2010; Verfaillie, 2000; Viviani, Figliozzi, Campione, & Lacquaniti, 2011). Although this ability is not demonstrated in newborns, one can hypothesize that they exhibit visual preference for BM over random motion because they infer apparent translation in BM displays but not in random motion displays. This assumption, however, requires additional experimental evidence.

## Conclusion

For the first time, the present work shows importance of the translational displacement in newborn's spontaneous visual preferences to semirigid motion. Human newborns are sensitive to horizontal translation component, and this sensitivity is rather independent of occurrence of biological kinematics. This opens a new window for better understanding the mechanisms supporting the spontaneous sensitivity of the human visual system for biological agents.

## Ethical Consideration

This experiment is part of a larger project focusing on the perceptual abilities of human newborns. All the experiments were approved by a committee of pediatricians, nurses, and parents from the maternity home of the "Clinique Mutualiste" in Grenoble. A committee from the French National Center for Scientific Research also approved the project. This experiment has been classified as purely behavioral testing involving no distress or discomfort to the newborns. At least one of the newborns' parents gave informed written consent and stayed close to their baby during the experiment without being visible to the child.

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