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Observational learning of a new motor skill: The effect of different model demonstrations

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Abstract

A central question in observational learning is which information is picked-up by the observers from a demonstration. Visual perception perspective suggested that relative motion information, such as those highlighted in point-light or stick-figure demonstrations, is extracted and used for reproducing the modeled action. This study was designed to examine this assumption by using a baseball-pitch as to-be-learnt motor task. Forty-one novice female and male adults were randomly assigned to three demonstration groups (video, stick-figure, and point-light) and a control group. Participants performed 5 trials in pretest, three blocks of 10 trial in acquisition phase, and two retention tests of 5 trials in 10 min and 7 days after last acquisition block. Intra- and inter-limb coordination patterns and movement time were measured at level of overall movement and individual movement phases as dependent variables. Results show that participants improved their coordination performance from pretest to acquisition blocks and retention tests, however, regardless of model observation. No significant difference was observed between groups in two retention tests. Analysis of movement phases showed a significant improvement in stride phase from pretest to acquisition blocks. Results are interpreted in terms of theoretical and methodological backgrounds. Further perspectives in research on observational learning are presented.

Keywords

Baseball pitching, intra-limb coordination, kinematics, modeling, motor memory, visual perception, relative motion information

Introduction

During the process of learning a new motor skill, learners have to acquire a new pattern of spatiotemporal coordination. Model demonstrations are extensively used by instructors and coaches as a teaching strategy to facilitate acquisition of new coordination pattern, especially in sport settings. A meta-analysis of research on observational learning revealed a moderate to strong effect size (0.77) on movement dynamics and a small effect size (0.17) on movement outcome.[1]

A topic of interest in observational learning is to identify what information is extracted by the observer from a demonstration for later replication. This issue has been addressed by visual perception perspective (VPP).[2] Mainly influenced by the visual perception theory of Gibson[3] and research in perception of biological motion,[4–6] VPP suggested that while observing a demonstration, relative motion information of the action, i.e. the spatiotemporal changes of body joints or extremities in relation to each other, is directly picked up and perceived by the visual system and later used to produce the action of the model. Moreover, it has been suggested that relative motion information available in a demonstration could be more effective in the first stage of motor skill acquisition, in which the learner attempts to assemble the efficient coordination pattern of the to-be-learnt movement.[2,7]

According to the VPP, a demonstration should be particularly effective when relative motion information of the movement is highlighted. That can be achieved by removing the structural information such as body shape, color, and so on from a demonstration through representing the human body in the form of a point-light or

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stick-figure display rather showing the observers a classic video containing structural information. As such, observing point-light or stick-figure demonstrations should result in better motor performance and learning than observing a classic video demonstration, because observers are able to extract relative motion information easily from point-light and stick-figure demonstrations rather than a classic video demonstration.

In the last decade, a growing body of research has emerged to test this assumption. Horn et al.[8] asked participants to learn a kicking action in soccer by observing a classical video demonstration or a point-light demonstration. In contrary with the assumption of the VPP, they observed no significant difference between video and point-light demonstration groups for neither outcome accuracy nor intra-limb coordination pattern. There was also no significant difference between demonstration groups and control group in any of measured variables. In the following experiment, Horn et al.[9] removed knowledge of result in order to make the model as the only source to convey information of to-be-learnt movement. Under this condition, participants in video and point-light demonstration groups did not reduce outcome error but showed a relatively accurate approximation of the intra-limb coordination of hip–knee to the model's pattern. In contrast, participants in the control group showed no improvement in movement coordination during practice. However, no significant difference was observed between video and point-light groups.

Using a similar methodology but a motor task including intra- and inter-limb coordination of upper and lower body, Breslin et al.[10] found that participants who observed either a video or point-light demonstration of a cricket bowling skill performed intra-limb coordination of the bowling arm significantly better than participants of control group. Observation of the model led also to a closer approximation of the movement time in comparison to control group. There was no significant difference between groups in terms of outcome scores or coordination of the nonbowling arm. In two later studies and using the same motor task, Breslin et al.[11,12] found some advantages for point-light demonstrations including whole body or the throwing arm over demonstrations showing only the wrist of the throwing arm or both wrists. A ''normal'' video demonstration was not included in these studies.

Altogether, based on the previous studies there have been conflicting evidence regarding the use of point-light display and it is not clear whether highlighting relative motion information in form of a point-light display plays a positive role on the observational motor learning process. Therefore, there is a clear need for additional research to confirm the effectiveness of using point light display in observational learning. The primary aim of this study, hence, was to extend the literature and to investigate further the hypothesis of VPP. As such, we compared the effects of observing point-light and stick-figure model demonstrations, which are assumed to highlight relative motion information, with a classic video demonstration, which is assumed to not highlight relative motion information, on motor performance and learning. As mentioned earlier, previous research has only compared a point-light demonstration with a video demonstration and the results showed no superiority for observing a point-light demonstration against a classic video demonstration. Current study also added stick figure display for further investigation in terms of motion perception. The baseball-pitch was chosen as motor task because it is a novel, complex, and multilimb sport skill. In order to evaluate skill acquisition, we compared the performance of the model and the participant in terms of intra- and inter-limb coordination pattern at the level of the overall movement as well as at the level movement phases. According to the VPP, it was hypothesized that point-light and stick-figure model demonstrations would lead to a better motor performance and learning in comparison to classic video model demonstration. It was also hypothesized that demonstration groups would perform better than control group in acquisition phase and retention tests.

Method

Participants

The participants were 41 females and males (mean age = 24.2 years) who had voluntarily participated in the study. The participants were randomly assigned to one of the four experimental groups: video, stick-figure, point-light, and control. Participants were right-handed and novices related to the motor task used in this study. Number of males and females was equal in all groups, 5 females and 5 males, with exception of video group consisting of 6 females and 5 males. This research has been performed in accordance with the Ethical Standards laid down in the Deceleration of Helsinki (1964). All participants gave written consent.

Task and production of model videos

A highly complex and dynamic throwing action, the baseball-pitch, was selected as motor task. The pitch consists of a clear phase structure including wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (the phases are presented in Table 1), which makes it possible to do a detailed analysis at the level of both overall movement and individual movement phases. In this study, the analysis of motor performance and learning was performed at the level of both overall movement and individual movement phases.

Table 1. Start and end points of the baseball-pitch phases with durations and allocated data points (pictures adopted with permission from Rojas et al.[13]).

Phase		Start- and end-point	Phase duration (s)	Data points
	1 Wind-up	Start point: Left foot elevated from ground End point: Left knee at the highest point	1.072	100
	2 Stride	Start point: Left knee at the highest point End point: Striding finished, throwing arm back	0.958	90
	3 Arm cocking	Start point: Striding finished, throwing arm back End point: right arm was cocked	0.168	15
	4 Arm acceleration	Start point: right arm cocked End point: ball released	0.093	10
	5 Arm deceleration	Start point: ball released End point: velocity of the right arm decreased	0.075	10
	6 Follow-through	Start point: velocity of the right arm decreased End point: right arm decelerated fully	0.236	25
	Overall movement	Start point: Left foot elevated from ground End point: right arm decelerated fully	2.602	250

A right-handed male pitcher (age = 32 years) with 7 years playing experience in the second baseball league of Germany acted as model. To produce stick-figure and point-light models, retro-reflective markers were attached to the forehead, shoulder, elbow, wrist, hip, knee, ankle, and toe joints on left and right side of his body. Four digital and synchronized cameras filmed spatiotemporal positions of markers while he performed a baseball-pitch. Simi Motion software 5.0^{TM} (SIMI Reality Motion Systems GmbH, Germany) was used for producing stick-figure and point-light videos. A normal video model was generated by using a digital video camera from a sagittal plane (Figure 1(a)). Point-light demonstration was constructed by recording movement of model with markers placed on the mentioned joints of the model and then processing the videos so that only the point-lights are visible in a darkened background (Figure 1(b)). A stick-figure demonstration was composed of the similar light points which are connected to each other with lines (Figure 1(c)). All demonstrations involved identical start and end points with four seconds duration.

Procedure

Participants were tested individually in 2 days. Prior to data collection, participants were given general information of the experimental process and then completed a questionnaire to get information such as age, gender, laterality, and previous experiences in baseball. Retro-reflective markers were placed on the upper and lower body parts of the participants in the same positions as the model. Finally, participants were given instruction of the baseball-pitch consisted of a series of images of

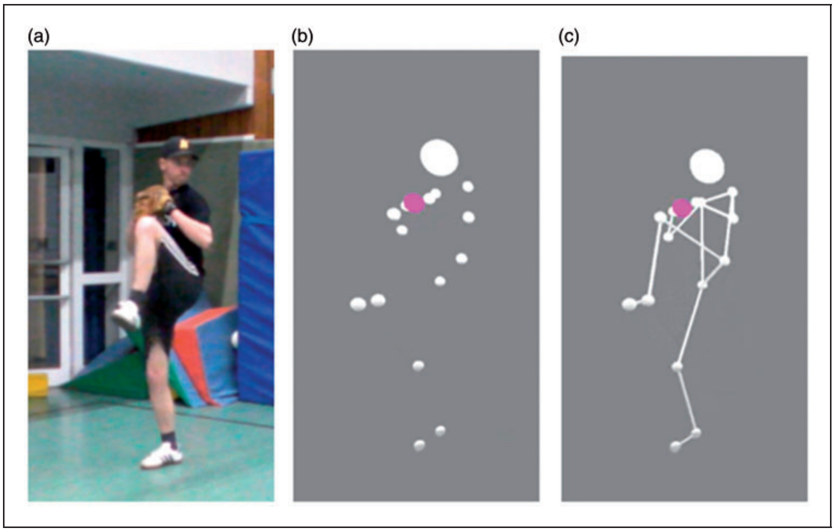

Figure 1. Screenshots of model demonstrations used in the present study: (a) normal video, (b) point-light, (c) stick-figure.

pitch phases following by extra notions of main features of the phases. We used these images even though there might be some potential pre-interventional learning; however, we considered it necessary due to the fact that baseball is a little known sport in Germany and the pitch represents a very complex sport skill. Participants were asked to perform the form of the pitch as correct as possible.

To familiarize with the experimental setting, participants performed two trials within a marked area of $1.1 \times 2.1\,m^2$. After five trials in pretest, participants performed three blocks of 10 trials in acquisition phase. Prior to each block, demonstration groups observed respective model video three times on a 17.3 inch laptop. Control group followed the same method but watched no model video. Finally, participants performed early and late retention tests each with 5 trials in 10 min after the last block and 1 week later, respectively.

Dependent variables

Kinematic data. Kinematic data was provided by comparing the coordination profile of each participant with that of the model. To do this, intra-limb coordination profile of upper and lower body limbs including throwing arm (right shoulder–elbow, because of its great range of motion in comparison to elbow–wrist coordination) and striding leg (left knee–ankle), and inter-limb coordination profile of right elbow–left knee were compared with those of the model.

In order to match the range of motion of the participant and the model, we performed a linear interpolation to normalize the start and end points of each movement phase. A number of data points were assigned to each phase based on the time the model took to perform respective phase (Table 1). We smoothed the data with a recursive fourth-order low pass Butterworth filter using a cut-off frequency of 7 Hz. The deviation of the intra- and inter-limb coordination patterns of the participant from that of the model was measured in terms of normalized root mean squared difference (NoRM-D[9]). The smaller the NoRM-D, the smaller the deviation of coordination pattern of the participant from that of the model.

Because of the large number of trials, we selected some of them for later analysis. We chose all trials on the pretest and retention tests and first three trials of each acquisition block. Therefore, 24 trials including five pretest, 3×3 acquisition blocks, and 2×5 retention tests were analyzed for all participants. NoRM-D score was separately calculated for overall movement and individual movement phases of the pitch.

Absolute movement time difference. Absolute movement time difference is defined as absolute difference between the times took the participant to perform the movement and that of the model and was measured for each individual phase of the pitch. Absolute time differences of all phases were added together to measure absolute time difference score for overall movement. Here, again, 24 trials were selected for later analysis. Movement time is a measurement of motor control.[10] For absolute movement difference variable, lower scores would indicate greater similarity with the model and negative scores would indicate that participants perform faster than the model.

Statistical analysis

One-way analysis of variance (ANOVA) was used to analyze the performances of the participants in the pretest and retention tests. The Scheffé test was used here, as in all other analysis, as post hoc test. Separate 4 (experimental groups) × 3 (acquisition blocks) ANOVAs with repeated measures on the last factor were used to analyze the performance development in the acquisition phase. Moreover, in two additional 4 (experimental groups) × 4 (pretest, acquisition blocks) ANOVAs the pretest was also included in the repeated measures analysis. Improvements from pretest to both retention tests were analyzed by using a 4 (experimental groups) × 3 (pretest, early and late retention tests) ANOVA. Significance level was set at $p < 0.05$.

Results

Intra-limb coordination

Shoulder–elbow. The angle–angle plots show that shoulder–elbow coordination of the participants differs in all experimental groups from that of the model, especially in stride phase, but the differences become smaller with practice (Figure 2).

NoRM-D results showed no significant difference between groups in pretest, early and late retention tests, $F = 1.76$, $p = 0.18$, $\varepsilon^2_{par} = 0.18$, $F = 0.70$, $p = 0.55$, $\varepsilon^2_{par} = 0.08$ and $F = 0.38$, $p = 0.76$, $\varepsilon^2_{par} = 0.04$, respectively. A significant main effect for time was observed from pretest to acquisition phase, $F = 4.73$, $p = 0.005$, $\varepsilon^2_{par} = 0.17$, but not for the groups, $F = 0.65$, $p = 0.58$, $\varepsilon^2_{par} = 0.18$, or group × time interaction, $F = 1.70$, $p = 0.11$, $\varepsilon^2_{par} = 0.07$. In acquisition phase, there was no significant main effect for group, $F = 0.26$, $p = 0.85$, $\varepsilon^2_{par} = 0.03$, block, $F = 1.66$, $p = 0.20$, $\varepsilon^2_{par} = 0.06$, or group × block interaction, $F = 0.67$, $p = 0.67$, $\varepsilon^2_{par} = 0.07$. A significant main effect for time was observed from pretest to retention tests, $F = 9.28$, $p = 0.000$, $\varepsilon^2_{par} = 0.26$, but not for the groups, $F = 0.65$, $p = 0.58$, $\varepsilon^2_{par} = 0.06$, or group × time interaction, $F = 2.30$, $p = 0.10$, $\varepsilon^2_{par} = 0.21$.

Results of NoRM-D values for pitch phases showed a significant improvement in stride phase from pretest to acquisition blocks as proved by a significant main effect for time, $F = 4.28$, $p = .004$, $\varepsilon^2_{par} = 0.17$. In late retention test, a significant main effect for group was observed in arm deceleration phase, $F = 5.66$, $p = 0.005$, $\varepsilon^2_{par} = 0.42$. Participants in the video and control groups were closer to the coordination pattern of the model than participants in the stick-figure group, $p = 0.01$.

Knee–ankle. The results of NoRM-D showed no significant difference between groups in pretest, early, and late retention tests, $F = 1.43$, $p = 0.25$, $\varepsilon^2_{par} = 0.15$, $F = 1.35$, $p = 0.27$, $\varepsilon^2_{par} = 0.14$ and $F = 1.26$, $p = 0.30$, $\varepsilon^2_{par} = 0.14$, respectively. There was a significant main effect for time from pretest to acquisition blocks, $F = 4.13$, $p = 0.009$, $\varepsilon^2_{par} = 0.15$, but not for the groups, $F = 2.52$, $p = 0.08$, $\varepsilon^2_{par} = 0.24$, or group × time interaction, $F = 1.36$, $p = 0.22$, $\varepsilon^2_{par} = 0.15$. In the acquisition phase, no significant main effect was observed for group, $F = 1.42$, $p = 0.40$, $\varepsilon^2_{par} = 0.15$, for block, $F = 0.92$, $p = 0.26$, $\varepsilon^2_{par} = 0.03$, or group × block interaction, $F = 1.45$, $p = 0.21$, $\varepsilon^2_{par} = 0.15$. A significant main effect for time was observed from pretest to retention tests, $F = 6.08$, $p = 0.004$, $\varepsilon^2_{par} = 0.19$, but not for the groups, $F = 1.37$, $p = 0.27$, $\varepsilon^2_{par} = 0.13$, or group × time interaction, $F = 0.78$, $p = 0.58$, $\varepsilon^2_{par} = 0.08$.

Results of analysis of the movement phases revealed a significant main effect for block in acquisition blocks in arm cocking phase, $F = 4.06$, $p = 0.03$, $\varepsilon^2_{par} = 0.14$. Participants improved their performances significantly in stride and arm acceleration phases from pretest to acquisition phase, $F = 7.81$, $p = 0.000$, $\varepsilon^2_{par} = 0.25$, and $F = 3.72$, $p = 0.01$, $\varepsilon^2_{par} = 0.13$, respectively. In late retention test, a significant difference was observed between experimental groups in arm cocking, $F = 5.64$, $p = 0.005$, $\varepsilon^2_{par} = 0.42$. In this case, participants in the video and point-light groups came closer to the model coordination pattern than participants in the stick-figure group, $p = 0.02$, and $p = 0.01$, respectively.

Inter-limb coordination

NoRM-D results revealed no significant difference between groups in pretest, early and late retention tests, $F = 2.22$, $p = 0.11$, $\varepsilon^2_{par} = 0.22$, $F = 1.67$, $p = 0.19$, $\varepsilon^2_{par} = 0.17$, and $F = 0.80$, $p = 0.50$, $\varepsilon^2_{par} = 0.09$, respectively. A significant main effect for time was observed from pretest to acquisition phase, $F = 7.37$, $p = 0.000$, $\varepsilon^2_{par} = 0.24$, but not for the groups, $F = 2.20$, $p = 0.11$, $\varepsilon^2_{par} = 0.22$, or group × time interaction, $F = 0.95$, $p = 0.48$, $\varepsilon^2_{par} = 0.11$. In acquisition phase, there was no significant main effect for group, $F = 1.18$, $p = 0.22$, $\varepsilon^2_{par} = 0.12$, for block, $F = 1.56$, $p = 0.33$, $\varepsilon^2_{par} = 0.06$, or group × block interaction, $F = 1.31$, $p = 0.27$, $\varepsilon^2_{par} = 0.14$. A significant main effect for time was observed from pretest to retention tests, $F = 14.05$, $p = 0.000$, $\varepsilon^2_{par} = 0.35$, but not for the groups, $F = 1.26$, $p = 0.30$, $\varepsilon^2_{par} = 0.12$, or group × time interaction, $F = 1.02$, $p = 0.42$, $\varepsilon^2_{par} = 0.10$.

Statistical analysis of movement phases showed a significant main effect for group in block in arm acceleration phase, $F = 3.95$, $p = 0.02$, $\varepsilon^2_{par} = 0.33$. Here, participants in the control group a significant stronger approximation to the model coordination pattern than participants in the stick-figure group, $p = 0.04$.

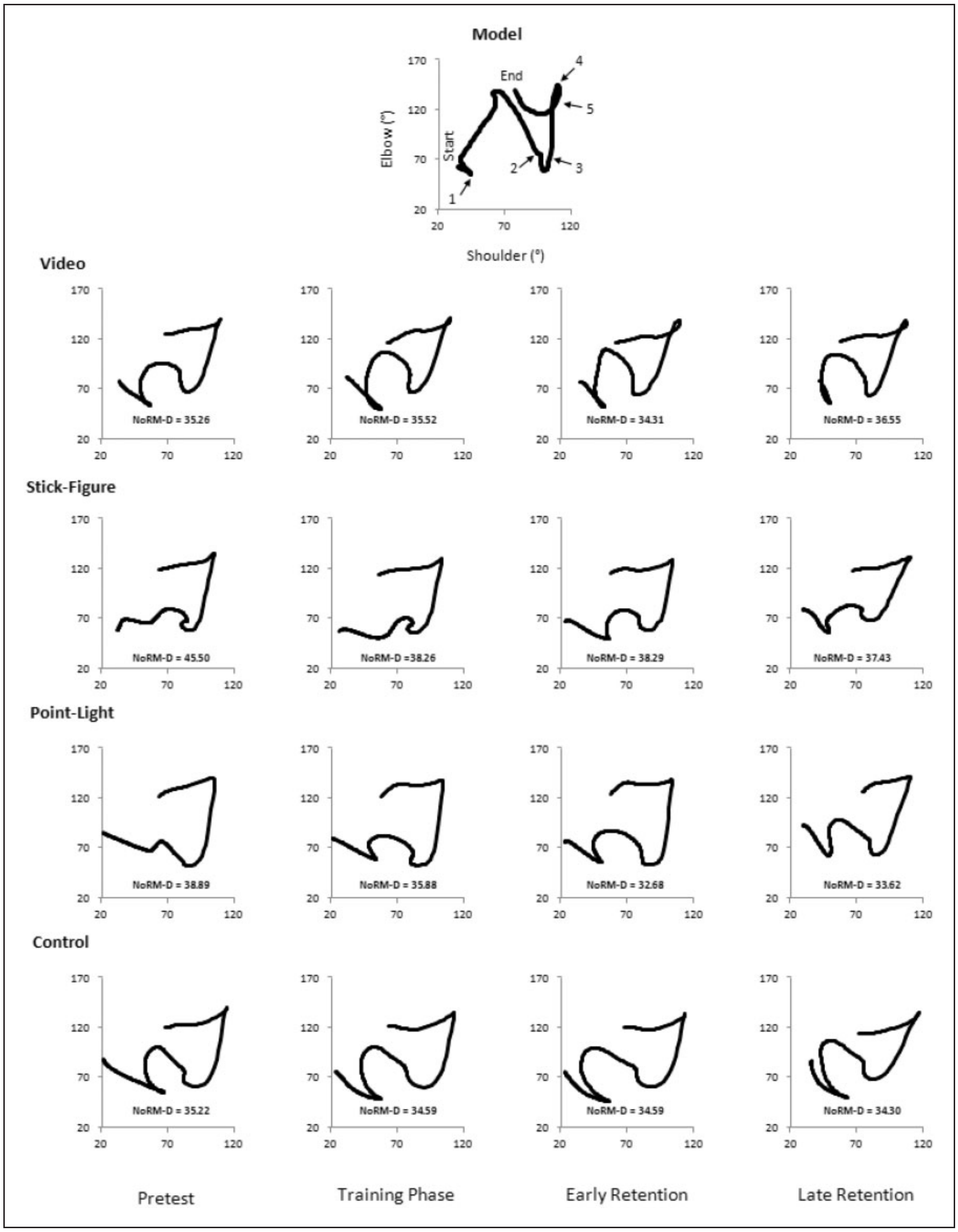

Figure 2. Intra-limb coordination of shoulder–elbow of the model (top) and experimental groups (top to bottom) across the pretest, the acquisition phase and the early and late retention tests (left to right). The numbers in plot of the model (top) represent the range of movement phases as the following: Start to number 1 (wind-up), number 1 to number 2 (stride), number 2 to number 3 (arm cocking), number 3 to number 4 (arm acceleration), number 4 to number 5 (arm deceleration), and number 5 to End (follow-through).

A significant main effect was observed for time from pretest to acquisition blocks in stride phase, $F = 9.26$, $p = 0.000$, $\varepsilon^2_{par} = 0.28$. There was a significant main effect for group in arm acceleration phase from pretest to acquisition block, $F = 4.47$, $p = 0.01$, $\varepsilon^2_{par} = 0.36$. In this case, participants in the control group were closer to the coordination pattern of the model than participants in the stick-figure group, $p = 0.03$. In early and late retention test, there was a significant difference between experimental groups in arm acceleration phase, $F = 4.00$, $p = 0.01$, $\varepsilon^2_{par} = 0.33$, and $F = 4.01$, $p = 0.02$, $\varepsilon^2_{par} = 0.34$, respectively. Participants in the control and video groups came closer to the coordination pattern of the model than participants in the stick-figure group in early and in late retention tests, $p = 0.03$, $p = 0.04$, respectively.

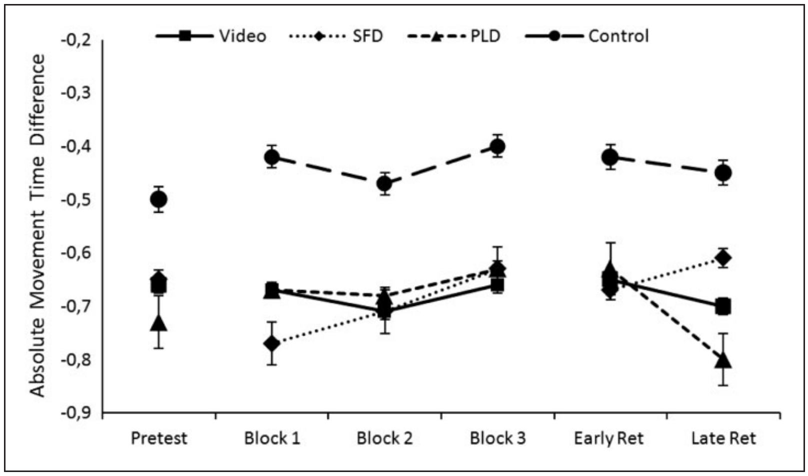

Figure 3. Mean absolute movement time difference for the experimental groups across pretest, acquisition blocks and retentions tests.

Absolute movement time difference

Figure 3 presents data of absolute movement time difference of overall movement. The results showed no significant difference between groups in pretest and early retention test, $F = 0.72$, $p = 0.54$, $\varepsilon^2_{par} = 0.06$, $F = 1.27$, $p = 0.29$, $\varepsilon^2_{par} = 0.17$, respectively. In late retention test, a significant difference was observed between experimental groups, $F = 3.00$, $p = 0.04$, $\varepsilon^2_{par} = 0.21$. Participants in the control group showed a significant approximation of the movement time to the model than participants in the point-light group, $p = 0.05$. In acquisition phase, no significant main effect was observed for group, $F = 1.58$, $p = 0.21$, $\varepsilon^2_{par} = 0.12$, block, $F = 2.59$, $p = 0.08$, $\varepsilon^2_{par} = 0.07$, or group × block interaction, $F = 0.73$, $p = 0.62$, $\varepsilon^2_{par} = 0.06$.

Results of movement phases revealed a significant main effect for block in acquisition blocks in stride phase, F=4.20, $p = 0.01$, $\varepsilon^2_{par} = 0.11$. A significant main effect for time in stride phase, $F = 3.15$, $p = 0.02$, $\varepsilon^2_{par} = 0.09$, was observed from pretest to acquisition blocks.

Discussion

The primary aim of the present study was to examine the hypothesis of the VPP, that relative motion information is picked-up and used by observers from a demonstration. According to this hypothesis, highlighting relative motion information within a demonstration, which could be achieved by generating point-light and stick-figure demonstrations, could result in better motor performance and learning in comparison to presenting the observers with a classic video demonstration, which involves all structural information. Therefore, in the present study we compared the effects of observing point-light and stick-figure model demonstrations with a classic video model demonstration on motor performance and learning of a baseball-pitch.

Generally, the results of intra- and inter-limb coordination patterns provided no support for this assumption, because there was no significant difference between demonstration groups in the acquisition phase or retention tests. Moreover, some evidence revealed that stick-figure demonstration group had even further approximation of movement pattern of the model than other experimental groups in some movement phases (e.g. arm cocking, arm acceleration, and arm deceleration). However, our findings are, in general, in accordance with the results of Horn et al.[9] and Breslin et al.[10] who found no superiority for point-light demonstration over video demonstration in observational learning. It appears from results of the present study along with results of the previous study that highlighting relative motion information within a demonstration does not necessarily guide changes in coordination.

It was also predicted that demonstration groups would show closer coordination pattern and movement time to the model than control group in acquisition phase and retention tests. This hypothesis was also not supported by the results; as participants in control group did not underperform participants in model demonstration groups in acquisition phase or retention tests. In other words, these results indicate that the video-based demonstration of the baseball-pitch, regardless of the form of demonstrations, had no positive influences on the motor learning process. Moreover, some evidence revealed that participants in control group showed closer movement time to the model than those in demonstration groups, e.g. in late retention test in terms of absolute movement time difference of overall movement or arm acceleration phase. Significant differences in movement phases between stick-figure group and control group might be because of poor performances of stick-figure participants in pretest and also because participants did not benefit from observing stick-figure model demonstration during acquisition phase. These findings are not in agreement with the results of Al-Abood et al.,[14] Horn et al.,[9] and Breslin et al.[10,12] who found model observation led to better motor performance and learning than no-model observation.

In our opinion, there are two possibilities which might interpret this contradiction. Firstly, it might be possible that amount of observational practice of our complex throwing skill was not sufficient to significantly improve the performance of demonstration groups during the acquisition phase. Secondly, presenting the participants with static images of pitch phases before the pretest might have prevented the effect of observing model demonstrations during the acquisition phase. An accurate look at the results of the pretest reveal that participants learned the baseball-pitch almost accurate at least in terms of throwing arm intra-limb coordination. Also, there were significant improvements from pretest to acquisition blocks and from pretest to retention tests in almost all measured variables, however, regardless of observing the model demonstration. It might indicate that the participants improved motor performances after pretest by physical practice and observing the model demonstrations had no positive effects.

These results raise the question if information of relative motion is extracted from static images of movement phases? The assumption of extraction of relative motion information was theoretically based on the Johansson's studies.[5,6] Johansson claimed that the individuals perceive motion of the points over time perception in a point-light display in order to recognize the biological motion, i.e. *form-from-motion* perspective.[15] More recently, some studies in biological motion perception introduced an alternative perspective called *motion-from-form* perception.[15,16] According to this perspective, perception of body form/posture over time is crucial for recognizing the biological motion, not perception of motion of points over time. In our opinion, it might be possible that the participants in our research perceived body/posture information rather than relative motion information from static images of movement phases and used them to replicate the action of the model. Future studies should be directed to investigating the extraction of body form/ posture information in the process of motor learning by observation.

A differentiated analysis of six phases of pitch showed that participants improved their performance in stride phase from pretest to acquisition blocks in all measured variables. It appears that significant improvements in coordination pattern from pretest to acquisition blocks occurred mostly in stride phase. It is obvious from angle–angle plot in Figure 2 that participants showed visually a large difference to the model in stride phase than in other phases. These results might indicate that stride phase of pitch is most effective phase to improve through practice. These results are important from practical point of view, because they provide a detailed examination of movement phases during the process of motor learning.

Conclusion

Results of the present study do not confirm the assumption of VPP regarding the extraction of relative motion information from a model demonstration. In addition, our research raise the question of what is the nature of information extracted from a series of static images of movement phases? In our opinion, it might be the information of body form/posture information over time. Therefore, we suggest that further studies should examine the extraction of body form/posture information from a model demonstration. Analysis of movement phases revealed that second phase of pitch, i.e. stride, is improved from pretest to acquisition blocks which might indicate that stride phase needs more practice than other phases.

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Declaration of Conflicting Interests

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