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*Corresponding author: Debopriyo Roy, School of Computer Science and Engineering, University of Aizu, Aizu-Wakamatsu City 965-8580, Japan
E-mails: droy@u-aizu.ac.jp; droyjapan@gmail.com

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An investigation into the efficacy of technical illustrations depicting physical orientation in sports procedures

Debopriyo Roy^{1*} and Stephen Crabbe²

Abstract: This study on mental imagery set out to investigate the efficacy of technical illustrations depicting physical orientation in sports procedures. The study was carried out by junior level students on an undergraduate degree in computer science at a Japanese technical university with no specialized knowledge of information design or visual communication. The study participants were asked to match body and overhead images shown from different height perspectives (waist and chest height) and camera positions (front, 1/3rd side, side, 1/3rd back, back) of a man holding a bat and a man hitting with a bat. These physical actions were selected by the researchers as they can typically be seen in multiple sports such as baseball, rounders or cricket, thus widening the potential applicability of the study findings. Overall, the study participants achieved relatively high levels of accuracy in matching the body and overhead images and no consistent or clear pattern emerged with regard to preferred height perspectives or camera positions. However, what can be suggested is that the study participants appeared to prefer - and the mean accuracy levels were higher for - viewpoints shown into the display plane. In addition, the study participants self-reported relatively high overall confidence in their matches

ABOUT THE AUTHORS



Debopriyo Roy

Debopriyo Roy is a Professor at the Center for Language Research, University of Aizu, Japan. He is a technical communication specialist and his research deals with information design, visual communication and usability for computer-assisted language learning in an EFL context. He obtained his PhD in Technical Communication from Rensselaer Polytechnic Institute, New York, and MA degrees in Communication and Economics. He is an active board member of the ACM chapter, and IEEE PCS Japan society, directs his own laboratory in technical communication, supervises research projects, and has publications in leading journals and conference proceedings.

Stephen Crabbe is a Senior Lecturer in Applied Linguistics and Translation (Japanese to English) at the University of Portsmouth, UK. The focus of his teaching and research is technical, professional and business communication and he is interested in supervising research students in any of these areas. He teaches multiple undergraduate and graduate courses and has many publications. He is also a Fellow of The Higher Education Academy.

PUBLIC INTEREST STATEMENT

This is a unique study in technical communication where technical illustrations were used to understand how users of technical manuals understand the procedure that shows physical actions with equipment as it unfolds. This study is interdisciplinary in nature, drawing from cognitive and behavioral psychology, and provides multiple examples of different body positions, camera angles and rotations that are typical for many sporting or other physical actions. The idea is to highlight the different factors in the design process that technical illustrators must consider when drawing technical illustrations for print or online user manuals. There is not much research in this area of study. Besides technical illustrators and visual communicators, this study should be helpful to instructors who want to offer an innovative technical course in visual communication and procedural instructions design.

despite not having any specialised knowledge of visual communication. It is hoped that this study and accompanying literature review could help technical communicators in thinking about how to design 2D technical illustrations and contribute to existing research into information design and visual communication, particularly in a sporting context.

Subjects: Sports and Leisure; Social Sciences; Communication Studies; Education

Keywords: 2D technical illustrations; camera positions; canonical viewpoint; display plane; information design; mental imagery; visual communication

1. Introduction

This study tried to investigate a challenging question in media and communication studies about how human cognition works when exploring 2D technical illustrations demonstrating physical actions. The discussions focused on an extensive overview of how mental imagery and mental models are created based on visual cues towards perception building for different sporting actions and physical movements.

Since the 1980s technical communicators have increasingly used illustrations to visually demonstrate physical orientation in procedures (Ganier, 2012). As a result, academics in the field of technical communication have started to conduct research into the most effective way(s) for technical communicators to do this. This research has involved participants using mental imagery, mental rotation and motor imagery¹ to match body and overhead images visually demonstrating physical orientation that are shown to the participants from different height perspectives and camera positions. By way of example, a study conducted in 2003 (Krull, D'Souza, Roy, & Sharp, 2004; Krull, Roy, D'Souza, & Morgan, 2003) asked participants (North American university students) to match body and overhead images shown from front, 1/3rd side, side, 1/3rd back and back camera positions of people driving a car, holding a box and performing fencing. The following set of hypotheses emerged from the above-mentioned study, and was considered for this research project.

- (1) Participants were more successful at matching the body and overhead images shown from the front and back camera positions than from the 1/3rd side, side and 1/3rd back camera positions.
- (2) The canonical viewpoint provides more information and makes it easier to understand the perspective and action.
- (3) Viewpoints into and across the display plane provide different kinds of information.

A more recent study conducted in 2014 (Roy & Crabbe, 2014) asked participants (Japanese university students) to match body and overhead images shown from front, 1/3rd side, side, 1/3rd back and back camera positions of people holding and throwing a ball. The findings of the study revealed that the participants found it slightly more difficult to match body and overhead images shown from the side camera position, and slightly easier to match body and overhead images shown from the back camera position, than from the front, 1/3rd side and 1/3rd back camera positions.

The current study builds on the 2014 study of Roy and Crabbe by looking at two physical actions with a sporting context: a man holding a bat and a man hitting with a bat. This was of interest to the researchers as a recent study in the field of sport psychology by Guillot, Moschberger, and Collet (2013) suggests that demonstrating physical orientation in sports procedures is more effective when motor imagery is consistent with physical practice. It is thus hoped that the findings of this study might help improve the efficacy of technical illustrations depicting physical orientation in sports procedures.

The study is significant from a number of perspectives. Firstly, this is a unique area of study in technical communication that has not been investigated extensively (except by Robert Krull and team) beyond the realm of psychology. In visual communication studies, this is still an area that is under-investigated to a large extent. So, this study is an attempt to fill the existing gap in literature. Previous studies in technical communication on technical illustrations design and body positions focused on driving positions, and holding a box from different related camera angles and heights. This study builds on that understanding. Secondly, using sporting actions as example test cases is unique, but the understanding and exploration about how 2D illustrations should be designed in those contexts augers well for other sporting or physical actions in entirely unrelated contexts. So, this study provides a general understanding about how certain types of body positions should be represented visually, and it also help readers and designers relate to how the audience might think and mentally animate an action in reality. Finally, this area of study in technical communication related to technical illustrations design opens up a new dimension to the teaching of visual communication pedagogy and usability. There are very few courses in visual communication or technical communication focusing exclusively on procedural instructions design.

2. Review of the literature

While researchers such as Heiser, Ginet, and Tversky (2002), Krull et al. (2003, 2004), Roy (2006) and Roy and Crabbe (2014) have started to look at the most effective ways for technical communicators to visually demonstrate physical orientation, the literature is still rather limited and further research is needed, particularly since, as pointed out by Ganier (2012), technical communicators are increasingly using illustrations to visually demonstrate physical orientation in procedures. The current study takes up this issue by examining perceptions of physical actions with a sporting context that are shown in 2D technical illustrations as a way to help improve the efficacy of technical illustrations depicting physical orientation in sports procedures. It should be noted at this point that the physical actions used in this study were selected, as they are not specific to any one sport. Rather, a man holding a bat and a man hitting with a bat could typically be seen in multiple sports such as baseball, rounders or cricket, thus widening the potential applicability of the study findings in multiple sporting contexts, or with studies where body positions related to an object in hand is being studied (sporting context or not).

This review of the literature is designed to provide an overview of four factors that can potentially influence the use and understanding of 2D technical illustrations in a sporting context.

1. Depth perception and the display plane
2. Skills involved in a physical action
3. Motor imagery
4. Motor learning

2.1. Depth perception and the display plane

Research undertaken in 2003 (Krull et al., 2003, 2004) suggests that technical illustrations showing physical actions should reflect the mental framework, or thought processes, of the readers who will carry out the actions in a physical environment. However, in a sporting context, the challenge with this is that when trying to comprehend different variants of body positions and physical actions in, for example, an illustrated sporting guide, people often need to perceive positions, objects, movements and forces along the line of sight into the display plane, thereby obscuring the vision necessary to enable the good perception of depth necessary to comprehend or replicate a given physical action.

Hochberg (1978, 1979) suggests that readers of 2D illustrations in print or electronic media have only monocular vision to help them interpret what they see. More recently, research by Erkelens (2010) has similarly suggested that monocular vision dominates binocular vision in experiencing depth in 2D illustrations. However, Schacter, Gilbert, and Wegner (2010) have also drawn attention

to the fact that monocular cues reduce depth perception in 2D illustrations, thereby making interpretation of them potentially more difficult. Depth perception arises from a variety of depth cues. These are typically classified into monocular cues that require input from just one eye and binocular cues that require input from both eyes (Goldstein, 2014). Ideally, a 2D technical illustration depicting physical orientation in a sports procedure should be able to emulate what is visible from a binocular vision to allow good perception of depth.

Similarly, research undertaken in 2003 (Krull et al., 2003, 2004) found that people are often able to comprehend the distance between objects or body parts across the display plane where the space between the objects or body parts is visible. However, people find it relatively difficult to judge positions when distances are judged into the display plane.

It is worth noting at this point that illustrators can also choose between showing physical actions from a spectator's viewpoint (seeing the action as an observer rather than the doer) or an object-centered viewpoint (seeing the action as the doer rather than as an observer). An examination of the relative efficacy of these viewpoints is beyond the scope of this literature review or study. However, interested readers may wish to consult Zacks, Mires, Tversky, and Hazeltine (2002) or Milner and Goodale (2006).

2.2. Skills involved in a physical action

A second factor that can potentially influence the use and understanding of 2D technical illustrations is the nature of the sporting task, the cognitive strategies it involves and the environmental conditions in which it takes place.

2.2.1. Skills classified by task

The use of technical illustrations to visually communicate a sporting task is influenced by the nature of the sporting task itself. To be specific, whether it involves a discrete action or a series of interconnected actions. For example, basketball is a game in which players score points by throwing a ball into the opposing team's basket. However, the task of throwing a ball to make the basket involves a series of discrete actions like gripping the ball appropriately while making the run, raising the arms to a certain angle, positioning the feet in readiness to jump, making the jump at the right time and then shooting the ball accurately. During the learning phase, these discrete actions are learned separately and then with more practice and reinforcement the actions are combined in a unified sequence. However, when readers look at an illustrated sporting guide showing how to throw a ball to make a basket they cannot see the sequence of actions required to do this in one static illustration. Rather, they need to look at a series of static illustrations showing each discrete action involved in the sequence while mentally simulating the task that is taking place.

2.2.2. Skills classified by cognitive elements

To continue with our example of the basketball game, a player who successfully makes a basket will have used both cognitive and motor skills to, for example, mentally decide on the precise nature of the jump and throw (how much to jump and the distance to throw) and then physically carry out the series of discrete actions involved. In other words, mentally and physically learning how to master the jump and throw requires a combination of cognitive and motor skills. Adolph and Berger (2006) suggest that a complex relationship exists between cognitive and motor skills development. Nevertheless, illustrated sporting guides (whether print or online) that show static illustrations might act as an aid towards the cognitive strategizing of the unified sequence of actions involved in, for example, making a basket until the performer reaches a point where the cognitive strategy is fully internalized and becomes automatic requiring little cognitive attention.

2.2.3. Skills classified by environmental conditions

Schmidt and Wrisberg (2008) point out that environmental conditions also impact on the level of cognitive skills required to identify and successfully perform physical actions. For example, a baseball player will likely need different strategies to allow him or her to hit with the bat when the

weather is windy or rainy and a tennis player will likely need different strategies to allow him or her to hold and swing the racquet on clay, grass and concrete tennis courts. The challenge for technical communicators is how to show tasks such as hitting with a bat or holding a racquet in different environmental conditions using static illustrations.

2.3. Motor imagery

A discussion of the efficacy of technical illustrations depicting physical orientation in a sporting context would not be complete without a consideration of motor imagery. This, as stated earlier, refers to the ability of humans to mentally simulate an action without physically doing it (Decety, 1996a, 1996b). Motor imagery thus allows players to mentally simulate a physical action in the prescribed or intended sequence. In addition, Guillot et al. (2013) suggest that demonstrating physical orientation with a sporting context is more effective when motor imagery is consistent with physical practice.

Two leading models of motor imagery are the PETTLEP model proposed by Holmes and Collins (2001) and the later MIIMS model was proposed by Guillot and Collet (2008) which both aim to help athletes develop effective visualization (Holmes & Collins, 2001; Wakefield, Smith, Moran, & Holmes, 2013).

This literature review will not look at these models in detail. However, it is worth briefly outlining the PETTLEP model. PETTLEP is an acronym for seven key factors to include when visualizing a physical action.

Physical: The physical elements of the action including the clothing and equipment used by the athlete.

Environment: The environment in which the action takes place.

Task: The details of what the action entails.

Timing: The pace at which the action takes place.

Learning: The image should match the current stage of learning of the athlete.

Emotion: Any emotions experienced by the athlete during the action.

Perspective: The way in which the athlete visualizes the action.

While the above factors aim to help athletes, it is clear that they also have the potential to assist technical communicators in thinking about how to design 2D technical illustrations depicting physical actions in a sporting context.

2.4. Motor learning

The final factor to be briefly considered in this literature review is motor learning. This is defined by Schmidt as a “set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for skilled behavior” (1988, p. 51). In this regard, an illustrated sporting guide may act as a supplementary aid towards facilitating motor learning through observed performance. In other words, consulting an illustrated sporting guide and observing physical practice may complement each other towards a more holistic understanding of the sporting task. It is thus hoped that the findings of this study might help improve the efficacy of technical illustrations such as those used in illustrated sporting guides to facilitating motor learning.

3. Research questions

The study has two research questions based on previous research done by Krull et al. (2003, 2004) and Roy and Crabbe (2014).

- (1) Is there any preference for the readers when it comes to choosing how they would like to visualize and mentally animate a physical action based on the information in 2D technical illustrations as seen in user manuals?
- (2) How confident are the readers in identifying specific user actions shown from different camera angles and movement along the horizontal and vertical axes?

4. Study sample and context

It should be made clear from the outset that this study has not been designed to directly assess motor imagery or motor learning. Rather, it has been designed to investigate the comprehensibility of technical illustrations demonstrating physical actions with a sporting context. Nevertheless, if any specific pattern emerges from the results, it may be possible to make tentative inferences about how motor imagery has been used for a given set of technical illustrations.

Forty-one participants took part in this study. The participants were native Japanese speakers with a pre-intermediate level of English in the third year of an undergraduate degree in computer science at a Japanese technical university. The study was undertaken by the students as an in-class and homework activity in an elective course taught primarily in English by the principle researcher. None of the students had taken courses in visual communication, information design, technical writing or any other area related to the study during previous academic years and neither was such a prerequisite for undertaking the study. Furthermore, the study was undertaken at the start of the course, thus the students had not yet acquired any specialised knowledge of information design or visual communication. The reason for undertaking the study at the start of the course was to limit any theoretical understanding of information design or visual communication on the part of the students that might influence the study results.

It should be made clear that, while, as noted above, the elective course is taught primarily in English by the principle researcher, the purpose of the study was not to test the English language ability of the students. Consequently, the students were given an instruction sheet on what they had to do in the study in Japanese. The same instructions were also repeated verbally by volunteer research assistants in Japanese. In addition, the information and questions on the study test sheets were given in Japanese. This was all done to ensure that that every student understood exactly what he/she had to do.

5. Methodology

The researchers generated 3D computer graphics images of body positions for two kinds of physical actions with sporting contexts: a man holding a bat and a man hitting with a bat. The images were generated using a virtual studio called Poser Figure Artist from E Frontier Inc. (<https://www.e-frontier.co.jp>). The purpose of having two kinds of physical actions was to explore whether the ability of the study participants to match body and overhead images was affected by the kind of action being shown.

Both actions were shown from chest and waist height perspectives. In other words, the man holding a bat was shown as holding the bat at chest and waist height with the hands gripping the bat on both sides. The man hitting with a bat was shown as hitting with the bat at chest and waist height with the hands gripping the bat on both sides. In all cases, the image of the man appeared on the screen as if being taken or looked at from just below his waist height.

Each of these four height perspectives was then captured from five camera positions (angular rotations): front or 0° (the man holding a bat/hitting with a bat while facing the camera head on), 1/3

side or 30°, side or 90 degrees, 1/3 back or 120° and back or 180°. A total of twenty body images (four sets of five images) were thus generated as illustrated in Figures 1 and 2.

Once the twenty body images had been generated, the researchers then positioned the camera to capture matching overhead images. A matching overhead image was generated for each of the twenty body images, with a displacement along the y and z-axis to position the camera exactly overhead. Finally, the researchers created twenty test sheets, as illustrated in Figures 3 and 4.

Each test sheet contained one of the twenty body images, three potential matching overhead images and the two questions shown in translation below. The Japanese text instruction in Figure 4 says the following:

- (1) Please study the image on top and the set of three images below. Which of the 3 images below taken from top camera angle represents the image on top (as seen from front).
- (2) Rank order the following three images below from the closest to the farthest to the front camera image.
- (3) How confident are you of your choice? (very confident, confident, somewhat confident, not confident, not at all confident)?

5.1. Participant task orientation

- (1) The study participants were given an instruction sheet in Japanese.
- (2) The volunteer research assistants also gave the same instructions verbally in Japanese.
- (3) Specifically, the study participants were told the purpose of the study, what sort of information was being sought and what they were being asked to do.
- (4) The study participants were also allowed to ask questions about the study, and to raise any issues or concerns they had, in Japanese.

Figure 1. Breakdown of the twenty body images.

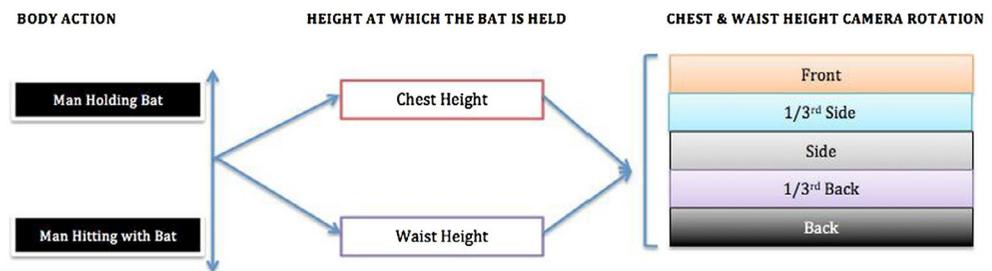


Figure 2. Example set: a man holding a bat at chest height (front, 1/3rd side, side, 1/3rd back, back).

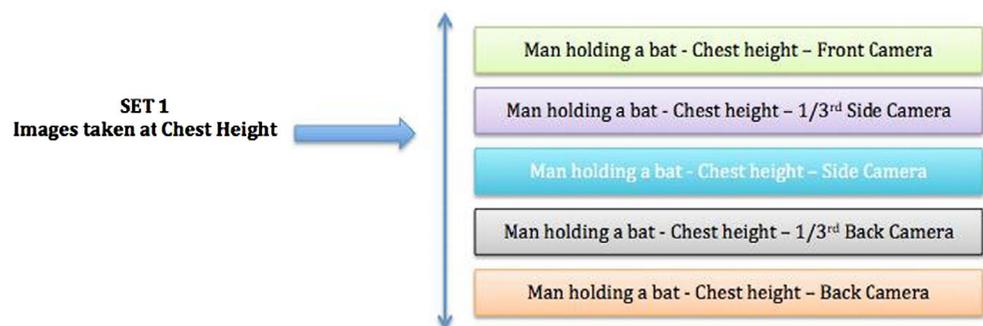


Figure 3. Example of a body and overhead image.

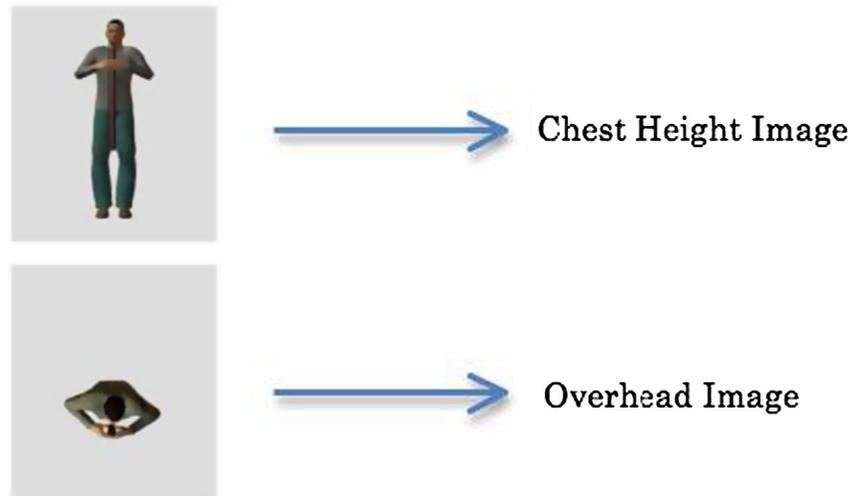


Figure 4. Example test sheet: a body image of a man holding a bat at chest height captured from the front with three potential matching overhead image.

Technical Illustration



Man holding Chest - front

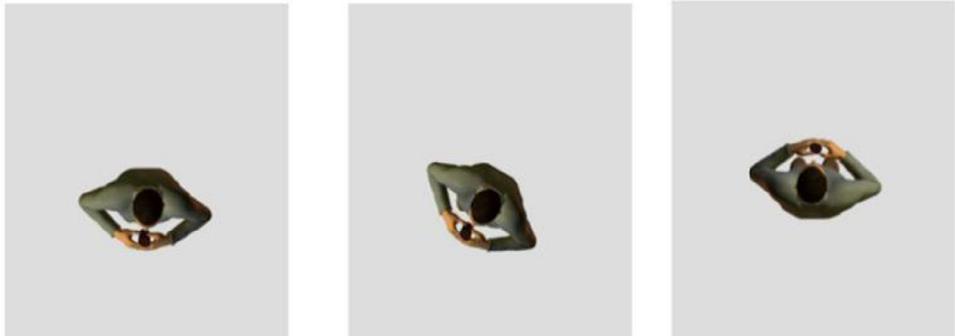
(1)上の写真をよく見て下に描かれた3枚の頭上から写された写真のうち同じものを示しなさい。

適当なものを丸で囲みなさい： A B C

(2)また、間違いの選択肢のうち最も正解に近いものはどれか。 _____
(e.g., A, B, C)

(3)あなたの答えについてどれくらい自信がありますか。

とてもある ある 普通 あまりない ない



(A) (B) (C)

- (5) The participants were categorically mentioned that the idea would be to test their visual perceptions about an image, and how it relates to the same image shown from a different perspective. It's a visual identification and matching task.
- (6) The study participants were also encouraged to explain to the volunteer research assistants why they think an image matches the other one shown from a different perspective. What visual cues prompted them to complete the matching task? However, it was not compulsory for participants to describe their pattern of mental imagery formation, or how they completed the mental rotation tasks.

The study was carried out as both an in-class and homework activity. The study participants had time in class to start the test sheets and then one week at home to complete them before the next class. The volunteer research assistants were available to help with any issues or concerns during this time period. The reason that the study participants were given a week to complete the test sheets was to ensure that they had time to think and re-think about the images and to change their initial responses if they so wished.

6. Tools and instruments

Poser Figure Artist software was exclusively used to design the technical illustrations for the test sheets. Each body position was designed manipulating the different camera angles, axes height and rotation of the figures. Once the body positions were designed, the images were exported as image files and saved in a desktop folder. *SurveyMonkey* was used to design each test sheet importing the images from the desktop, with enough follow-up text instructions to complete the task and move from one test sheet to another. The *SurveyMonkey* URL was then posted in *Moodle*—the learning management system for the participants to access it. Data analysis was done using *SPSS*, and the data was saved imported in *Google Drive* for further analysis. The experiment took place in a classroom environment where students had the opportunity to ask questions to the instructor.

7. Findings

For question 1 on the test sheets, the researchers gave the study participants a score of 1 for a correct answer and 0 for an incorrect or unanswered question. For question 2, the study participants gave themselves a score in the range of 1 to 5 (1 being not at all confident, 2 being not confident, 3 being somewhat confident, 4 being confident and 5 being very confident). The researchers gave the study participants a score of 0 if the question was unanswered. The resulting data was analyzed using the statistical software *SPSS*.

Table 1 shows the responses given by the study participants for question 1 on the twenty test sheets. The responses are shown in the following order:

- 5 camera positions or angular rotations (front, 1/3rd side, side, 1/3rd back, back) for the man holding the bat—chest height
- 5 camera positions or angular rotations (front, 1/3rd side, side, 1/3rd back, back) for the man hitting with the bat - chest height
- 5 camera positions or angular rotations (front, 1/3rd side, side, 1/3rd back, back) for the man holding the bat - waist height
- 5 camera positions or angular rotations (front, 1/3rd side, side, 1/3rd back, back) for the man hitting with the bat—waist height.

The “Mean” and “Std. Deviation” columns reveal that there are differences in the accuracy of the responses given by the study participants for question 1. First, the “Mean” column shows that the mean accuracy scores for the man hitting with the bat were, except for the man hitting with the bat at waist height from the back camera position, consistently lower than for the man holding the bat for each camera position (angular rotation) and height combination. Second, the “Std. Deviation” column shows that the standard deviations for the man hitting with the bat were, except for the man hitting with the bat at waist height from the front and back camera positions, consistently higher than for the man holding the bat for each camera position (angular rotation) and height combination.

Table 1. Mean accurate responses for the 5 angular rotations for man with bat—holding/hitting—chest/waist height

	Mean	Std. Deviation	Frequency		
			0	1	
Holding chest front	.85	.358	6	35	Cochran's Q = 4.182
Holding chest 1/3 side	.93	.264	3	38	
Holding chest side	.85	.358	6	35	
Holding chest 1/3 back	.83	.381	7	34	
Holding chest back	.88	.331	5	36	
Hitting chest front	.78	.419	9	32	Df = 19
Hitting chest 1/3 side	.83	.381	7	34	
Hitting chest side	.78	.419	9	32	
Hitting chest 1/3 back	.66	.480	14	27	
Hitting chest back	.85	.358	6	35	
Holding waist front	.85	.358	6	35	Asymp. Sig = .382
Holding waist 1/3 side	.88	.331	5	36	
Holding waist side	.85	.358	6	35	
Holding waist 1/3 back	.90	.300	4	37	
Holding waist back	.93	.264	3	38	
Hitting waist front	.90	.300	4	37	
Hitting waist 1/3 side	.68	.471	13	28	
Hitting waist side	.76	.435	10	31	
Hitting waist 1/3 back	.80	.401	8	33	
Hitting waist back	.93	.264	3	38	

The researchers next used a nonparametric Cochran's Q Test for binary data (1 = correct; 0 = incorrect or unanswered) to test for statistically significant differences in the accuracy of the responses for question 1 across the five camera positions (angular rotations).

Table 2 shows the Cochran's Q Test for the images of the man holding the bat at chest height across the five camera positions (angular rotations). This shows that the Cochran's Q value is 4.182, the Sig. value is .382 and *p* is greater than .05. There is thus no statistically significant difference in accurate responses across the five camera positions (angular rotations).

Table 3 shows the Cochran's Q Test for the images of the man hitting with the bat at chest height across the five camera positions (angular rotations). This shows that the Cochran's Q value is 6.552, the Sig. value is .162 and *p* is greater than .05. There is again no statistically significant difference in accurate responses across the five camera positions (angular rotations).

Table 2. Cochran test for holding chest height—5 angular rotations

	Conchran's Q	Df	Asymp. Sig.
Holding chest front			
Holding chest 1/3 side			
Holding chest side	4.182	4	.382
Holding chest 1/3 back			
Holding chest back			

Table 3. Cochran test for hitting chest height—5 angular rotations

	Conchran's Q	Df	Asymp. Sig.
Hitting chest front			
Hitting chest 1/3 side			
Hitting chest side	6.552	4	.162
Hitting chest 1/3 back			
Hitting chest back			

Table 4. Cochran test for holding waist height—5 angular rotations

	Conchran's Q	Df	Asymp. Sig.
Holding waist front			
Holding waist 1/3 side			
Holding waist side	2.615	4	.624
Holding waist 1/3 back			
Holding waist back			

Table 4 shows the Cochran's Q Test for the images of the man holding the bat at waist height across the five camera positions (angular rotations). There is again no statistically significant difference in accurate responses, as revealed by the Cochran's Q value of 2.615, the Sig. value of .624 and *p* being greater than .05. However, the data does reveal that there is less disparity in accuracy for the images of the man holding the bat at waist height than for the images of the man hitting with the bat at chest height.

Table 5 shows the Cochran's Q Test for the images of the man hitting with the bat at waist height across the five camera positions (angular rotations). With the Cochran's Q value of 14.122, the Sig. value of .007 and *p* being less than .05, there is a statistically significant difference in accurate responses. The data also shows that there is greater disparity in accuracy for the images of the man hitting with the bat at waist height than for all the other sets of images.

Figure 5 shows the mean accuracy scores for the images of the man from the front camera position for each physical action and height combination. This reveals mean accuracy scores of between 78 and 90%.

Figure 6 shows comparable levels of accuracy for the images of the man from the 1/3rd side camera position for each physical action and height combination, except for the image of the man hitting with the bat at waist height at 68%.

It can also be seen that, overall, the mean accuracy scores suggest that it was easier for the study participants to match the images of the man holding the bat irrespective of whether it was at chest or waist or taken from the front or the 1/3rd side camera position.

Table 5. Cochran test for hitting waist height—5 angular rotations

	Conchran's Q	Df	Asymp. Sig.
Hitting waist front			
Hitting waist 1/3 side			
Hitting waist side	14.122	4	.007
Hitting waist 1/3 back			
Hitting waist back			

Figure 5. Mean accurate responses for front position with different combinations of man with bat—holding/hitting/ chest height/waist height.



Visual Angles	Mean	Std.Deviation
Holding chest front	.85	.358
Hitting chest front	.78	.419
Holding waist front	.85	.358
Hitting waist front	.90	.300

Figure 6. Mean accurate responses for 1/3rd side position with different combinations of man with ball—holding/hitting/ chest height/waist height.



Visual Angles	Mean	Std.Deviation
Holding chest 1/3 side	.93	.264
Hitting chest 1/3 side	.83	.381
Holding waist 1/3 side	.88	.331
Hitting waist 1/3 side	.68	.471

Figure 7. Mean accurate responses for side position with different combinations of man with ball—holding/hitting/ chest height/waist height.



Visual Angles	Mean	Std.Deviation
Holding chest side	.85	.358
Hitting chest side	.78	.419
Holding waist side	.85	.358
Hitting waist side	.76	.435

Figure 7 shows the mean accuracy scores for the images of the man from the side camera position for each physical action and height combination. The mean accuracy scores for the images of the man hitting with the bat have relatively lower levels of accuracy (76–78%) than for the man holding the bat (85%).

Figure 8 shows the mean accuracy scores for the images of the man from the 1/3rd back camera position for each physical action and height combination. This shows that the mean accuracy score for the image of the man hitting with the bat at chest height is at 66% far lower than any other combination.

Figure 9 shows the mean accuracy scores for the images of the man from the back camera position for each physical action and height combination. This reveals there to be a comparable level of accuracy (85–93%) for the different physical actions and height combinations.

The researchers next explored the levels of confidence that the study participants self-reported in question 2. Table 6 shows the mean confidence levels across the five camera positions (angular rotations) for the man holding the bat at the chest height position. This reveals that the study participants had high overall mean confidence levels for matching the images of the man from the front and 1/3rd side camera positions.

Table 7 reveals that the study participants had comparatively less mean confidence levels for matching the images of the man hitting with the bat at chest height than for the man holding the bat at chest height. This is particularly the case for matching the images of the man from the front and 1/3rd side camera positions, which dropped from 3.98 to 3.43 and 3.95 to 3.55 respectively.

Figure 8. Percentage of accurate responses for 1/3rd back position with different combinations of man with ball—holding/hitting/chest height/waist height.



Visual Angles	Mean	Std.Deviation
Holding chest 1/3 back	.83	.381
Hitting chest 1/3 back	.66	.480
Holding waist 1/3 back	.90	.300
Hitting waist 1/3 back	.80	.401

Figure 9. Percentage of accurate responses for back position with different combinations of man with ball—holding/hitting/chest height/waist height.



Visual Angles	Mean	Std.Deviation
Holding chest back	.88	.331
Hitting chest back	.85	.358
Holding waist back	.93	.264
Hitting waist back	.93	.264

Table 6. Mean Confidence levels for the 5 angular rotations for man with bat—holding—chest height

Visual angles	Mean	Std. deviation
Holding chest front	3.98	1.050
Holding chest 1/3 side	3.95	1.061
Holding chest side	3.50	1.177
Holding chest 1/3 back	3.80	.966
Holding chest back	3.63	1.254

Table 7. Mean confidence levels for the 5 angular rotations for man with bat—hitting—chest height

Visual angles	Mean	Std. deviation
Hitting chest front	3.43	1.217
Hitting chest 1/3 side	3.55	1.061
Hitting chest side	3.55	.986
Hitting chest 1/3 back	3.63	1.125
Hitting chest back	3.48	1.219

Table 8 shows the mean confidence levels across the five camera positions (angular rotations) for the man holding the bat at the waist height position. This reveals that the mean confidence levels steadily increased as the camera position (angular rotation) moved away from the front.

Table 9 shows the mean confidence levels across the five camera positions (angular rotations) for the man hitting with the bat at the waist height position. This reveals that, apart from the back camera position, the mean confidence levels generally decreased as the camera position (angular rotation) moved away from the front.

Table 8. Mean confidence levels for the 5 angular rotations for man with bat—holding—waist height

Visual angles	Mean	Std. deviation
Holding waist front	3.58	1.196
Holding waist 1/3 side	3.63	1.192
Holding waist side	3.75	1.056
Holding waist 1/3 back	3.78	1.209
Holding waist back	3.85	1.051

Table 9. Mean confidence levels for the 5 angular rotations for man with bat—hitting—waist height

Visual angles	Mean	Std. deviation
Hitting waist front	3.78	1.074
Hitting waist 1/3 side	3.68	1.207
Hitting waist side	3.53	1.198
Hitting waist 1/3 back	3.53	1.154
Hitting waist back	3.63	1.192

Table 10. Significant correlations between mean accuracy and confidence scores

Correlations between	Pearson value	Sig. value
Holding chest front	.356*	.024
Holding chest 1/3rd back	.499**	.001
Hitting chest 1/3rd side	.354*	.025
Hitting chest back	.463**	.003
Holding waist 1/3rd side	.319*	.045
Holding waist 1/3rd back	.344*	.030
Hitting waist 1/3rd side	.462**	.003

*Indicates 5% level of confidence.

**Indicates 1% level of confidence.

It is clear from the discussion of the findings that there are some differences in the mean confidence levels across the images. The researchers thus used a non-parametric Friedman Test to identify whether the differences were statistically significant. The χ^2 value is 37.587 and the asymp. Sig. value is .007 < .05 ($p < .05$). This reveals that there is significant difference in confidence levels as reported for the twenty images. The researchers then tested the bivariate correlation between the mean accuracy scores and confidence levels. However, this did not reveal any clear pattern as can be seen in Table 10. However, significant correlations between mean accuracy scores and confidence score was observed hitting-holding positions for waist and chest heights for all rotational angles.

8. Discussion

The data obtained from perspectives or camera sports procedures. The study does not provide a clear answer as to preferred height positions for technical illustrations depicting physical orientation in sports procedures.

For the front camera position or spectator’s viewpoint that shows more angles across the display plane, we see mean accuracy levels of 85–90% for the man holding and hitting with the bat at waist height and holding the bat at chest height, but a slightly lower mean accuracy level of 78% for the man hitting with the bat at chest height.

Similarly, for the 1/3rd side camera position that is a truly canonical viewpoint putting maximum angles across the display plane, we see mean accuracy levels of 83–93% for the man holding and hitting with the bat at chest height and holding the bat at waist height, but a lower mean accuracy level of 68% for the man hitting with the bat at waist height. There is, however, no explicable reason for this. For the illustrations showing a hitting position, the arms are shown apart, the bat is more on a horizontal axis and the legs are wider apart when compared to the holding position. All these features would have allowed the study participants to see more angles across the display plane. Conversely, for those illustrations showing a holding position, the legs are closer, the arms are more towards the vertical axis and the bat is on a vertical axis standing between the legs. This should have technically created more difficulty for the study participants when they were viewing the matching overhead images. This is because the bat and arms are then positioned into the display plane and thus difficult to decipher from overhead.

For the side camera position, that is less canonical in nature showing less objects across the display plane when compared to the 1/3rd side camera position, the accuracy levels varied from 76–85% for all the body-height-action combinations. We see a similar performance for the back camera position, with the accuracy levels varying from 85–93% for all the body-height-action combinations. Contrarily, for the 1/3rd back camera position, which is more canonical when compared to the back camera position, we see mean accuracy levels of 80–90% for the man holding and hitting with the bat at waist height and holding the bat at chest height, but a lower mean accuracy level of 66% for the man hitting with the bat at chest height.

The study participants also self-reported relatively high overall confidence in their choices despite not having any specialised knowledge of visual communication or information design.

Overall, the study participants achieved high levels of accuracy in matching the body and overhead images and no clear or consistent pattern emerged with regard to preferred height perspectives or camera positions. However, what can be suggested is that the study participants appeared to prefer—and the mean accuracy levels were higher for—viewpoints shown into the display plane.

In addition, undertaking the study and accompanying literature review has enabled the researchers to develop a checklist to assist technical communicators in thinking about how to design 2D technical illustrations depicting physical actions with a sporting context.

1. Are all the required and relevant elements of the sporting task shown in the illustrations?
2. Are the illustrations shown in a way that allows readers to mentally simulate the sporting task in the prescribed or intended sequence?
3. Do the illustrations help readers develop a logical consistency between motor imagery and observed performance?
4. Can the illustrations act as a supplementary aid towards facilitating motor learning through observed performance?
5. Do the illustrations show the sporting task into or across the display plane?
6. Is the height perspective appropriate for the sporting task being illustrated?
7. Is the camera position appropriate for the sporting task being illustrated?
8. Is every discrete action in a unified sequence of actions included in the illustrations?
9. Do the illustrations take into consideration relevant environmental conditions?
10. Do the illustrations take into consideration the current stage of learning of the readers?

This study is considered a continuation of the studies done by Krull et al. (2004) where the researchers showed that illustrations depict a body schemata that integrate visual thinking with a person's sense of the body (Parsons, 2001). Further, researchers (Dixon & Gabrys, 1991; Kieras & Bovair, 1984) have mentioned the value of declarative information suggesting that subjects only benefited from declarative information that specified the relationship between equipment controls and subject's related physical action sequence.

In our study, the readers were not provided with any practice or no extra cues through text-based explanation or supporting graphics that could potentially facilitate the understanding about the relationship between the bat and body position and leads to some form of learning about the task. Participants were simply oriented orally about the task that they needed to complete, and volunteers ensured that everyone understood the task in hand. No supplementary instructions were provided to ensure there is no practice effect resulting from text or supplementary visual instructions. In other words, this study only tested participant's ability to perform mental imagery and mental rotation tasks successfully, without any supplementary affordance.

Thus, in this experiment, orientation about the bat, gripping positions through zoomed-in images and/or text explanation, and other descriptive examples could have yielded better results, or different significant preferences for body positions. So, this raises the question about when and how to use minimalist information, and if such minimalist approach is suitable for procedural information showing physical action sequences. This is an important issue to consider for future studies because people can build mental models of 3D spaces from verbal instructions, as well as for illustrations (Paivio, 1971).

Another related question for the discussed experiment in this study is the fact that verbal overview of spatial configurations yielded faster performance when people perform steps (Bryant, Tversky, & Franklin, 1992). This experiment did not present readers with a verbal overview of spatial configurations including the height of the bat, how to hold it, related body positions, surrounding environment including wind factors, focus and concentration etc. Also, this study did not identify concrete steps in the process of executing the actions. Holding the bat and hitting with the bat was considered as one action, and that was how the test sheet illustrations were demonstrated. Future studies should look into how identifying different concrete steps in the action sequence could change the outcome. It could be likely that some action sequences in a related series of action are better recognized and mentally animated with imagery formation, when compared to some other images in the same sequence.

Another aspect of the illustrations used for this study is the fact that the focus was on the overall body positions related to the action. But in addition to using visual information, brain perceives some actions from a body-centered perspective of kinesthetic information telling them the position of limbs, heads, neck muscles, and eyes (Greer, 1984; Johnson, 1984). The test illustrations in this study did not focus on these aspects specifically.

Also, a very important aspect left out from this experiment and should be considered in future studies is the reaction time required (in seconds) for different combinations of body positions, actions, camera heights, and rotations. Krull et al. (2004) also mentioned that people might perform differently depending on the content of illustrations (objects or bodies) and the kinds of operation they are asked to perform. For example, hitting with a bat and defending a ball are vastly different actions requiring different body positions, feet movement, bat position etc. Also, readers should be asked about whether they are paying attention to objects in illustration or on how the human body needs to act. These aspects should be looked into separately for future studies.

One important limitation of the current study is that we asked readers to make very fine judgments among body positions. For inexperienced readers, making subtle judgment of distances across and into body positions could be a problem. Similar to Krull et al. (2004) study, this study also had the rotations captured around the vertical axis of the display plane. Rotations made across the display plane are easier to capture visually. But technical illustrations in real life user guides may be rotated around different axes, including both into and across the display plane without restrictions.

Also, future research should consider this more as a usability study with a screen capture of user actions, verbalization of their interest, focus, attention, irritation, cognitive load etc. Usability research could further look into eye tracking of user actions. That kind of data will be interesting to suggest how readers think and what they look at when completing the action. Eye tracking data combined with reaction time would be a valuable indicator of user preferences in technical illustrations of this nature. Follow-up retrospective interviews and re-visiting user action video recordings would also present valuable data about user emotions.

9. Future studies and conclusion

There are several ways in which this study could be broadened in future research to add to and clarify its findings.

First, visual contextual elements could be increased to show, for example, the positions of other athletes, clothing and environmental conditions. Comparative studies could be run based on similar or dissimilar sporting actions and positions.

Second, the study participants could be asked to view both technical illustrations and actual physical practice of the sporting procedure to investigate whether they complement each other towards a more holistic understanding of it, and if mental imagery and rotational task performance improves over time with repeated visual exposure.

Third, the study was undertaken at the start of a course taught by the principle researcher so as to limit any theoretical understanding of information design or visual communication on the part of the study participants. However, a follow-up study could be undertaken at the end of a course to investigate whether, and by how much, an increased understanding of information design and visual communication on the part of the study participants affected the study results. However, such a study could only be run successfully by identifying the confounding and independent variables.

Fourthly, the images used for this study appeared on the screen as if being taken or looked at from just below waist height. A future study could use technical illustrations shown from other viewpoints to investigate their comparative efficacy.

Finally, the current study built on the 2014 study of Roy and Crabbe by looking at the efficacy of technical illustrations depicting physical orientation in two sports procedures. The researchers hope that their findings, while preliminary, can help technical communicators in thinking about how to design 2D technical illustrations depicting physical actions with a sporting context. They also hope that they will contribute in some measure to existing research into information design and visual communication, particularly in a sporting context.

In conclusion, this study could be generalized for other physical contexts, body positions and postures, and object types, using very similar principles of design and body positions as mentioned in the literature related to cognitive and behavioral psychology, and other related studies in technical communication. Future researchers should keep in mind that in order to improve the design of procedural instructions as mentioned by Ganier (2004), technical writers need to know how users proceed from their initial reading to executing described actions. That needs a complete synergy between users, document and equipment.

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Author details

Debopriyo Roy¹
E-mails: droy@u-aizu.ac.jp, droyjapan@gmail.com
Stephen Crabbe²
E-mail: stephen.crabbe@port.ac.uk

¹ Center for Language Research, School of Computer Science and Engineering, University of Aizu, Aizu-Wakamatsu City 965-8580, Japan.

² Faculty of Humanities and Social Sciences, Department: School of Languages and Area Studies, University of Portsmouth, Park Building, King Henry 1 Street, Portsmouth PO1 2DZ, UK.

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Note

1. Mental imagery is used here to mean creating a mental image of an object without direct visualization of it (Amorim, Isableu, & Jarraya, 2006), mental rotation to mean then rotating this mental image (Hertzog & Rypma, 1991; Johnson, 1990; Jones & Anuza, 1982) and motor imagery to mean the ability of humans to mentally simulate an action without physically being engaged in it (Decety, 1996a, 1996b).

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