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TOWARDS MOVEMENT-BASED INTERACTION FOR TAWAF TRAINING INVESTIGATING ITS SUITABILITY FOR OLDER ADULTS

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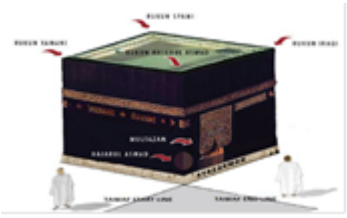
Graphical abstract



Abstract

Training of Tawaf (a rite in Hajj- the Muslim pilgrimage) has been limited to traditional method of text-reading and talk-listening. An edutainment approach of virtual environment simulation training could offer a more immersive experience through realistic Tawaf settings. Constructing a more natural interaction style for the virtual training, besides enhancing its realism value, could be the missing link in providing the engagement factor that appeal to older users. This paper describe a preliminary study in finding out a first indication on whether a natural interaction style through body movements could also be suitable for older users. Encouraging results showed that there is little difference in gesture performance of Istilam (a Tawaf gesture) between group of adult participants and group of older (age above 60) participants, suggesting the applicability of movement-based Tawaf training interaction to older adults as well.

Keywords: Gesture, natural interaction, tawaf, edutainment

1.0 INTRODUCTION & MOTIVATION

The Hajj, a pilgrimage to Mecca, Saudi Arabia is performed at least once in a lifetime by Muslims around the world. In some countries, training is annually conducted by the official governing body of Hajj management to assists in the preparation of the Hajj candidates. A main objective of the training is 'to increase the candidate's awareness of the conditions and situations in the actual Hajj' [6]. This is important as Hajj consists of several rites that are mentally, emotionally and physically demanding. Therefore, a training method that represents the Hajj as accurately as possible could help the candidates be absolutely prepared.

We narrow our problem scope to the training of the Tawaf, one of the more challenging rites in Hajj. During Tawaf, a pilgrim has to move, in harmony, with thousands of other pilgrims circling the Kaaba (the epicenter structure of the Tawaf), seven times in a counter clockwise direction. Pilgrims also have to perform several Tawaf gestures in each of the circling. The main training methods for Tawaf have been focused on textbooks, talks and seminars. In line with the training objective mentioned earlier, a practical training approach had recently been added. In this approach, trainers lead the candidates in performing a simulation of the Tawaf, by circling a scaled model of the Kaaba at a designated wide-open space. In Figure 1, the upper depicts an actual Tawaf scene, and the lower depicts an example of the simulation training.

Figure 1 Actual Tawaf [8] vs Simulation Tawaf

At a glance, this training approach appears to be more comprehensive and realistic than just text-reading and talk-listening. Nonetheless, to acquire further understanding and gauge the effectiveness of this approach, we obtained permission from the trainers to observe and record the entire simulation without any interference to the study subjects (the Hajj candidates). Upon examination of the recorded videos, we single out the most important concern: a large number of study subjects fail to perform the Tawaf gestures in each lap. Upon closer observation, most of these subjects are of the older generation (60 years and above). These elderly candidates also depict some difficulty in keeping up with the crowd, difficulty in following the trainer's instruction, and often looking overwhelmed and lost in the whole process of the simulation. Based on subsequent discussions with the trainers, we conclude that what the candidates have learned through textbooks and talks prior to the simulation, not all of them were able to apply it during the simulation. Despite the effort in making the training to be as similar as possible to the actual Tawaf, it remains difficult to motivate older candidates to participate and respond accordingly to the instructions given. An alternative or a complementary training approach that can accommodate the older candidates but still preserve the realistic portrayal of the Hajj is needed. An interactive 3D virtual environment can offer a similarly immersive training through realistic depiction of the Hajj scene, and incorporate suitable stimulus that can motivate the users to respond accordingly.

Training through virtual simulation can be likened to training using digital games [11]. The concept of Hajj itself is quite similar to games, making it suitable for an educational entertainment approach for training. In Hajj, pilgrims need to perform several tasks and challenges to complete a certain rite before moving on to the next rite. In this aspect, it is similar to games design, where challenge is a necessary component to advance to the next level. Basically, by incorporating this kind of gaming stimulation, on top of providing rich media content, users might be more motivated to execute and complete tasks accordingly. Furthermore, research has shown that the physical and emotional state of health of the elderly persons is affected positively by playing or exercising with digital games [5, 15]. Research has also shown that movement-based games can motivate the older users to response in maintaining a basic level of activity [10].

While a 3D virtual Hajj training simulation could offer a visually realistic Hajj scene, the main goal of our research is to convey a sense of realism through user interaction, since we believe that it can elicit greater response from the users. More importantly, we would like to focus on how to achieve this to include older set of users. Presently, most 3D virtual environment application users take form of 'avatars' (a digital representation of oneself) to interact which are controlled using joystick, or mouse and keyboard. The work of [2] is an example of a Hajj training application using avatar representation that is controlled using mouse and keyboard. However, we cannot expect the elderly to be efficient in using these devices as it still requires the user to learn how to perform the interaction (e.g. clicking the mouse to select) and equate them to real-world actions (e.g. clicking equals to selecting).

Reference [4] addresses this issue as the "Gulf of Execution" and the "Gulf of Evaluation". The "Gulf of Execution" depicts the challenge that a user face to convert their intention into commands to perform a task. The "Gulf of Evaluation" depicts the challenge that a user faces to understand the state of the system from the interface's feedback, after a task has been executed. Needless to say, these issues would be magnified when dealing with elderly users. Most importantly, it would also defy the main objective of making this training as realistic as possible to the actual Tawaf.

One possible solution is to leverage familiarity to the users through interactions that are similar to real world interactions, and make use of the skills and techniques the users already possess [3, 12, 13]. It also enables the users to automatically understand the effect of their actions. For example, grasping an object using our hands and carry it to a new location is definitely more understandable than clicking an object using a pointer and dragging it to a new location. This has been demonstrated by movement-based games such Wii®, where research has shown

that the Wii games bring the engagement factor through Kinesthetic Mimicry movements–movements patterned after real world movements [16]. By providing familiarity with real-world movements, it makes it easier for users to play and master a certain game. Users also quickly understand the effect of their actions in the game world; for example, the force put into the swinging of the Wiimote® as a tennis racket will determine the speed of the ball. Essentially, by increasing the engagement factor in the interaction [1], we can hope for more response from the users.

We believe that this style of interaction offer much resemblance to the nature of the Tawaf ritual itself, which involves a lot of natural body movements using hands and legs, and intuitive body movements, such as walking to arrive to a destination. The latest technology of interaction devices that breaks free from the confinement of keyboard and mouse could be exploited to promote a more natural and intuitive interaction. Using this technology, we set to find the right kind of interaction language to help ease the burden of cognition of older candidates, keeping in mind the range of motion, agility and strength.

2.0 INTERACTION ISSUES IN TAWAF TRAINING

We collaborated with domain experts and trainers of Hajj to set a research definition of Tawaf in the context of the movement flow of a pilgrim:

"A Tawaf requires the pilgrim to circle the Kaaba seven times, in a counter clockwise direction. The circling begins at the eastern corner of the Kaaba where the Black Stone (*Hajarul Aswad*) is placed, at which the pilgrim is encouraged to touch and kiss the stone. If this is not possible, the pilgrim can greet the stone through other particular hand gestures. The pilgrim will then continue to the other three corners of the Kaaba, the Iraqi Corner (*Rukun Iraqi*), Syami Corner (*Rukun Syami*), and the Yemeni Corner (*Rukun Yamani*) - and touch the Yemeni Corner, if possible- before arriving back to the Black Stone. The pilgrim will then repeat the same circling manner for the next six laps. During the circling, it is recommended for the men to make the first three laps at a quick pace, followed by the next four laps at a normal pace. Pilgrims are also encouraged to recite supplications during the circumambulation."

The movement flow is depicted in Figure 2. From the definition given, we structure the guidelines that directly involve gestures and body movements into three different categories: Circumambulation, Istilam, and Supplication. Pilgrims need to complete several forms of body movements and gestures to complete the tasks in each category which are:

1) *Circumambulation*
- a) *Walk:* walk at a normal unhurried pace
- b) *Ramal:* jog or walk at a hurried pace
- c) *Navigate:* turn body at each corners of the Kaaba

2) *Istilam*
- a) *Kiss Stone:* kiss the stone once
- b) *Touch Stone:* either with one hand or both hands
- c) *Isyarah:* greet stone using several forms of gestures

3) *Supplication*
- a) *Dua:* pray before and after Tawaf

For each task, we propose a particular sequence of body movements (referred to as Tawaf gestures henceforth) that match the description above. At this point several issues become apparent. Tawaf are based on rules which includes tasks that are wajib (obligatory) and tasks that are sunnah (encouraged). Isyarah task for example is sunnah, and as there is a perceived notion that the sunnah rule is less stringent, performance variations in Isyarah gestures should be expected. Also, since the users of the training system would have to perform these gestures seven times, it might further cause irregularities in gesture performance for all seven executions. Moreover, like in the actual Tawaf, users would have to perform these gestures while walking or jogging (Ramal) circling the Kaaba and thus the added exertion factor could further affect the performance of the Tawaf gestures. At the heart of these issues is the fact that users of Tawaf training would be from wide-range age groups. Hence the issues above should be addressed to ensure that gestures would be suitable for users of different ages. Our first step in addressing this issue is to investigate the extent of differences or changes in gesture performance that these issues bring to the users. Our current concern is that whether these Tawaf gestures, while developed based on Tawaf tasks and guidelines, would also be suitable for the elderly candidates. To address this concern, we have carried out a preliminary user study, described in the next section.

3.0 PRELIMINARY STUDY

A preliminary study was conducted to investigate the performance of single handed Tawaf gestures with focus on duration, distance and speed. The effects of exertion and the extent of user variations and performance consistency were examined. Twelve participants (four females) were acquired, and divided into two groups: six falls into the Group 1 category (age 60 to 75) and the rest are in Group 2 (age 22 to 30). All participants were right-handed, with no motor or cognitive disorders. Three of the participants (age 22, 23, 30) had used camera-based systems such as Kinect before. The Tawaf gestures selected for this study are two forms of *Isyarah* tasks (under the Istilam category), and will be referred to as *Isyarah1* and *Isyarah2* henceforth. The *Isyarah1*

gesture requires participant to raise their right hand just above the head, and bring it down to the mouth to kiss the fingers (Figure 3). The *Isyarah2* gesture requires participant to walk in place continuously, and lift the right hand across the head to the left side, while looking to the left (Figure 4). *Isyarah* gestures were chosen as we have noted that most of the Hajj candidates were having difficulty when performing Istilam during the Tawaf practical simulation.

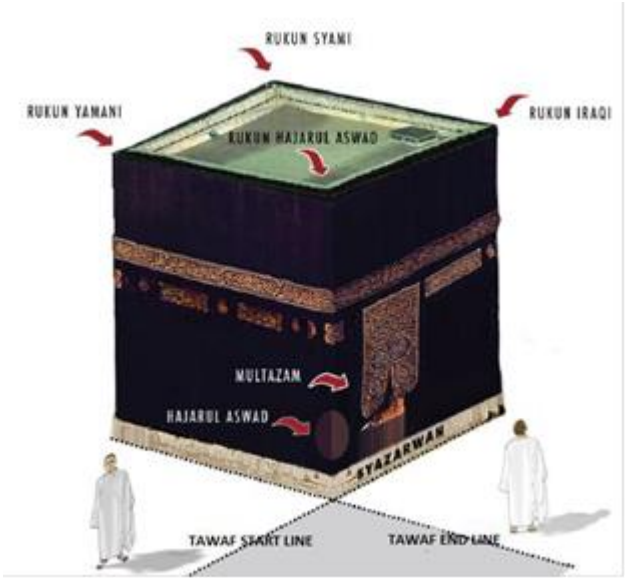


Figure 2 Kaaba illustration showing the movement direction of Tawaf [8]

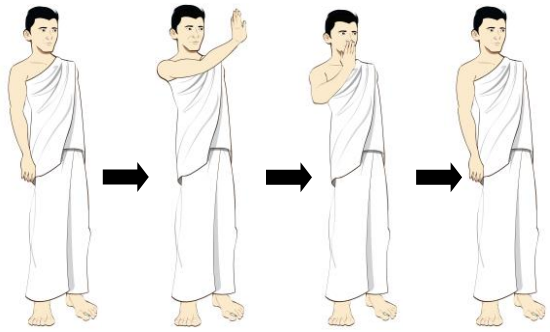


Figure 3 Sequence of the *Isyarah1* gesture

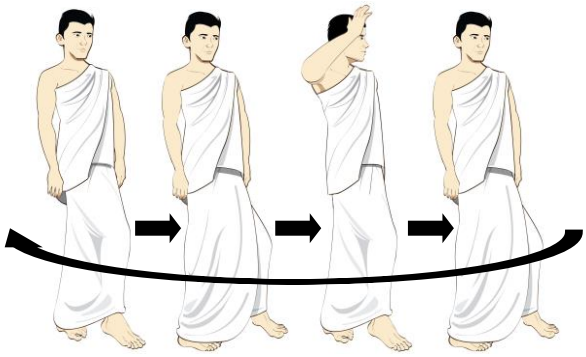


Figure 4 Continuous sequence of the *Isyarah2* gesture

To avoid preconception, participants were not told that the gestures are for a Tawaf training simulation. Participants were firstly given a one-time demonstration for gesture Isyarah1 by an instructor. Each of them then performs Isyarah1 seven times consecutively, each time at the signal of the instructor, who also monitors the recording of the gestures. Following that, one-time demonstration of Isyarah2 was given. Participants were required to walk in place for two minutes, and then while still walking in place; participants performed the required hand gestures seven times, again each time at the signal of the instructor. Participants performed the gestures seven times to match the number of circling of a Tawaf.

The joints movements of the participants were tracked with a Kinect® sensor. The positions of the joints were captured and sampled at 30 frames per second, which was then analyzed in MATLAB® R2012b to generate tables of joint coordinates (x, y, z) over time. For the purpose of comparison discussion in this paper, only the coordinates of the elbow joint were presented. The justification is that in these Isyarah gestures, the movements and directions of the hand are mainly controlled by the elbow.

4.0 RESULTS AND DISCUSSIONS

A total of 168 gesture motions were collected. The gestures data were processed to acquire duration, distance and speed data. Duration represents the time duration (in seconds) of the gesture motion. Distance represents the distance travelled (in the 3D plane - translates in meters) by the elbow joint during the gesture motion. Speed represents the distance covered per unit of time.

For this feasibility study, although the participants were encouraged to perform the gesture as similarly as possible to the instructor's version, strict exactness was not the main criteria being investigated. Rather we are interested to see how the gesture performance differs between participants especially in older participants. As the performance of the participants is compared against each other, and not against the instructor, we do not include in the following discussions the gesture performance measurements (of duration, distance and speed) of the original instructor's version. However, it is important to note that all gestures were successfully completed by the participants, meaning that the gestures were all correctly done in terms of the movement motion similar to the instructor's version.

4.1 Evaluation of Group Performance

Since each measurement of duration, distance and speed have seven data, the mean value from the seven data were calculated. From these individual mean values, we calculated the mean value for each group. Next the percentage difference

between both groups for each measurement of duration, distance, speed was derived. Based on the results shown in Figure 5, for the Isyarah1 gesture, the percentage difference between Group 1 and Group 2 for average duration, distance and speed is 12%, 6% and 17% respectively. Isyarah2 gesture recorded a higher percentage difference between both groups for average duration, distance and speed; at 14%, 11% and 22% respectively.

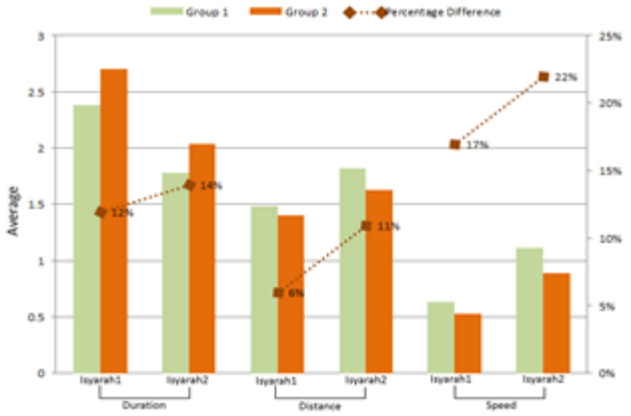


Figure 5 Percentage difference between group 1 and group 2

Observing the results of Isyarah1, the relatively low percentage difference for average duration suggests that both groups used similar time duration to perform the gesture. The very low percentage difference in total distance means that both groups are able to maintain similar form of gesture movement, in terms of its absolute size. The low percentage difference in average speed showed both groups share consensus on how quickly or slowly the movements of the gesture is to be done.

Meanwhile, observing the higher total of percentage difference for Isyarah2, we attempt to determine the reason by video examination, and find that Group 2 in average hold the position of the hand much longer and steadier than Group 1, and that Group 1 participants tend to bring down their hand more quickly, which could be due to tiredness. These contribute to the percentage difference for average duration between both groups. We also noted that Group 1 participants produce bigger form of gesture movement. This could suggest that exertion caused the older participants to have poor control and coordination of their joints. These contribute to the percentage difference between both groups for average distance. The relatively high percentage difference in average speed showed a stronger indication of how exertion could affect the performance of the older participants. Group 2 showed a lower movement speed because their movement is much more controlled and steadier, even if they are tired by the walking, as opposed to Group 1.

The gesture Isyarah1 has an explicit start and end motion, whereas Isyarah2 is intended to be continuous, with the participants walking in place during the whole recording session. We chose to add the exertion factor as we are interested to see how significant the changes in gesture performance will be, especially on the older participants. Besides, in the actual Tawaf, the pilgrims would actually have to perform these gestures while walking circling the Kaaba and thus this added factor made the experiment more similar to the actual Tawaf. Overall, it is perceived that the percentage difference between both groups is relatively low for the entire category of duration, distance and speed. This shows that generally there is little difference in gesture performance between both groups. To further support this claim, statistical analyses were done. The non-parametric equivalent to the t-test analysis, Mann-Whitney U Test is used to test the results of the gesture performance of the two groups to determine whether there is significant difference in gesture performance of participants who are 60 years and older, and participants who are below 60 years of age. The test is executed to the three measurement category; duration, distance, and speed of both gestures Isyarah1 and Isyarah2. The null hypothesis is: "there is no significant difference in gesture performance between the two groups; meaning the two groups can't be distinguished by the performance measurement of time duration/ distance/ speed alone". The results shown in Table 1 do not suggest a statistically significant difference between Group 1 and 2 (given $p \leq .05$, 2-tailed). Thus the null hypothesis is not rejected, and we can conclude that there is no significant difference in gesture performance between the two groups in terms of time duration, distance, and speed.

Table 1 Summary of Mann-Whitney U Test results

	U-value	P-value
Isyarah1		
Duration	12	0.337
Distance	13.5	0.470
Speed	10.5	0.229
Isyarah2		
Duration	13	0.420
Distance	9.5	0.173
Speed	10.5	0.229

4.2 Evaluation of Individual Performance

As the Hajj candidates need to circle the Kaaba seven times in the actual Tawaf, we are also interested to see the changes in gesture performance between the 1st execution (representing the first circling lap) and the 7th execution (representing the last circling lap). We compare the seven executions of each

measurement of duration, distance and time. The null hypothesis is: "there is no significant difference in the participants' gesture performance (in terms of time duration/distance/speed) for all seven executions". The results of the Friedman Test (the equivalent to non-parametric ANOVA) in Table 2 do not suggest a statistically significant difference between the seven executions (given p≤ .05, 2-tailed) for each measurement of duration, distance and speed; hence the null hypothesis is not rejected.

Additionally, since both Isyarah1 and Isyarah2 are our most complex gestures yet in the Tawaf interaction library, we are concerned whether the gestures would be hard to learn, executed and memorized, especially for the older adults, and might cause irregularities in gesture performance for all seven executions. Thus, to obtain a general outlook on the consistency and variability of the participant's performance, we calculated the percentage change for each seven execution for both Group 1 and Group 2.

Table 2 Summary of Friedman Test results

Measurement	N	Chi-Square	df	p-value
Isyarah1				
Duration	12	8.099	6	0.231
Distance	12	5.821	6	0.444
Speed	12	1.964	6	0.923
Isyarah2				
Duration	12	9.988	6	0.125
Distance	12	6.322	6	0.388
Speed	12	7.214	6	0.301

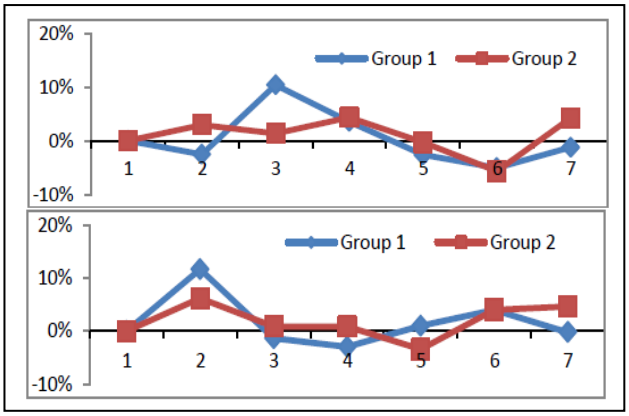


Figure 6 The percentage change for duration between each execution of the Isyarah1 (above) and Isyarah2 gesture

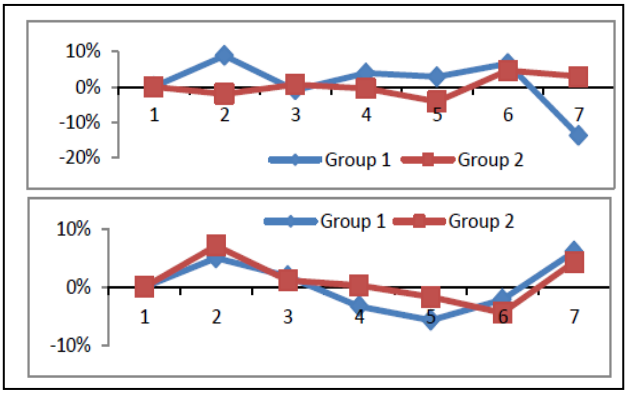


Figure 7 The percentage change for distance between each execution of the Isyarah1 (above) and Isyarah2 gesture

Observing the results of the percentage change depicted in Figure 6 and 7 for duration and distance, Group 2 performance for both Isyarah1 and Isyarah2 showed more consistency throughout the seven executions. For speed (Figure 8), both groups do not show high consistency, though Group 2 performance is slightly more consistent (based on the number of nodes that is closer to the axis). Also, Isyarah1 produces more variability (based on the non-similar line pattern) between Group 1 and 2 for duration, distance, and speed. Isyarah2 showed variability for duration but less variability for distance and speed.

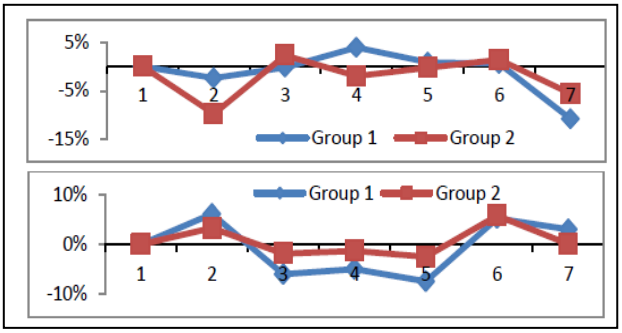


Figure 8 The percentage change for speed between each execution of the Isyarah1 (above) and Isyarah2 gesture

Generally, this preliminary study provides us with more insights on the challenges in designing movement-based interaction for Tawaf training. Several of these insights are:

Exertion effect – Even though the gesture motion for Isyarah2 is simpler than Isyarah1, the exertion factor (walking in place) increases the percentage differences between the two groups, signifying a likely effect on older users. Since the exertion factor is a necessary component to convey a realistic Tawaf experience, rather than eliminating it, a better solution is to incorporate a fatigue management in the interaction design [10] e.g providing options on

the degree of gesture complexities of the sunnah tasks for the older users.

Consistency - Although the percentage difference between both groups increases for Isyarah2, the percentage change between each seven executions were rather consistent for both groups. This might show that the number of executions for Tawaf training (seven times) is still acceptable for each individual to maintain the same degree of gesture performance.

Accuracy versus Variability - Gestures with more than one type of movements (e.g. Isyarah1) tend to produce more variability in terms duration, distance and speed. While the gestures should be designed based on the Tawaf rules and guidelines; it should be flexible enough to allow variations in terms of duration, distance and speed. As discussed earlier, this is because of the sunnah nature of some of the Tawaf gestures, and as shown in the study results, there is an inherent variability in the gestures between users.

5.0 CONCLUSIONS AND FUTURE WORK

The gestures derived serve as a very basic interaction library for Tawaf simulation training, to be assessed and improved through more future user studies, as we continuously investigate its suitability and general applicability. For the preliminary study presented in this paper, the observations serve more as trend indicators and in future work we hope to verify it with more suitable-sized data sets. However, the results presented here are very encouraging, indicating that the tested gestures are suitable for the older participants as well. Since there is no previous work that we are aware of on constructing movement-based interaction for a virtual simulation-based Tawaf training, and especially one that is mindful on the interaction for older users, we hope to eventually serve it as the gestural interaction library for the most ideal Tawaf performance for the training of broad age-range of users. Therefore we hope that it will bring significant contribution to the Hajj training research field, and help encourage the elderly to take active part in Hajj training and benefit from it.

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