microforce: A Comparison of Macro and Micro Gestures regarding the Manipulation of 3D Objects in Augmented Reality

ABSTRACT

Gestures are an intuitive input method for Augmented Reality systems which have become more and more desirable with the technological advances in hand and finger tracking. AR-devices like the Microsoft HoloLens commonly use macro gesture interfaces which can cause fatigue and let the user feel uncomfortable when using them in public. These limitations can be resolved by only using small motions with the wrist, palm and fingers – known as micro gestures. In this research, both gesture sets are compared regarding their efficiency, productivity and user experience for 3D operations by running a within-subject user study. The results show a significant advantage in efficiency and productivity for the defined micro gesture interface in complex operations like rotating and scaling. Only the move operation was performed better with the macro gesture set.

CCS CONCEPTS

• Human-centered computing~Gestural input • Human-centered computing~User studies • Human-centered computing~Mixed / augmented reality

KEYWORDS

Augmented Reality; AR; gestural interaction; human computer interaction; human-centered computing; Leap Motion; macro gestures; micro gestures, Microsoft HoloLens; mid-air gestures; mixed reality

1 Introduction

Augmented Reality (AR) creates an enhanced user experience by adding virtual graphics, sounds, and touch feedback into our natural world. Optical See-Through Head-Mounted Displays (OST-HMDs), generally in the form of goggles or a specialized visor, feature a transparent display in front of one or both eyes in which digital information is superimposed onto real life vision. Microsoft develops and manufactures an OST-HMD called HoloLens[1]. At the front of the HoloLens headset, there are sensors and related hardware such as cameras, processors, and other input/output components. Enclosed in the tinted visor that sits over a user's eyes, there is a pair of transparent combiner lenses, in which the projected images are displayed in the lower half of the visor's display [8].

To manipulate the virtual graphics and holograms, a gesture-based interaction is used. In fact, gestural interfaces have become increasingly popular in the commercial market over the past few years. Hand gestures allow users to act in Augmented Reality. Mid-air gestures, concretely defined as "air-tap" and "bloom", are the core gestures for interaction in the HoloLens [1]: the user holds their hand in front of the HoloLens with an approximate distance of 30 cm and tapping with their index finger, or opens the hand with the palm facing upwards (see chapter Prototype). Mid-air gestures can be highly appealing for AR application, but researchers have found some disadvantages such as fatigue or imprecision and may be perceived as socially awkward when using an AR device in public [5, 6]. Moreover, the execution of mid-air gestures requires free space around the user to avoid unwanted accidents. In this paper, mid-air gestures are called macro gestures.

An alternative solution to the problems associated with macro gestures is direct manipulation with micro gestures. Micro gestures are described as detailed gestures that allows the execution in a reduced interaction space [12]. Given their potential, micro gestures have been discussed as both primary and secondary topics by other researchers and can become a much more suitable form of direct manipulation in AR applications. Nonetheless, a direct comparison with macro gestures is widely unexplored at the time of writing.

So far, the following question has remained unanswered: Is direct manipulation of virtual objects in an Augmented Reality OST-HMD application with micro gestures more accurate, productive, and/or pleasant to the user than direct manipulation with macro gestures?

To answer this research question, a prototype was developed. The Microsoft HoloLens and the Leap Motion were the technological base. After defining a gesture set for macro and micro gestures, the prototype was tested by twenty-three

[1] https://www.microsoft.com/de-de/hololens

study participants. The measurements and usability aspects were evaluated afterwards.

2 Related Work

2.1 Mid-Air Gestures in Augmented Reality

Theil et al. [14] have carried out the comparison between use-case-specific mid-air gestures across contrasting applications to identify the most recurrent ones. 15 gestures were identified as the most common ones; pointing, waving, and swiping are three examples of these 15 gestures. Often, touch-based actions and their characteristics have been translated to a mid-air interaction.

Piumsomboon et al. [12] focused on hand gestures for unimodal input in AR. A total of 800 gestures were generated for 40 tasks. They noticed that a virtual object´s size influences the interaction pattern.

2.2 Fatigue in Mid-Air Interactions

Mid-air interactions are prone to fatigue and lead to a feeling of heaviness in the upper limbs, a condition termed as the Gorilla Arm Syndrome [2]. Fatigue levels are determined as the amount of time a person can maintain a static muscle contraction. This can be measured by the heart's response to increase blood flow to transport oxygen to the muscle fibers. Hincapié-Ramos et al. [7] introduced Consumed Endurance as a metric to characterize shoulder fatigue in mid-air interactions. Hincapié-Ramos et al. also advise that when possible, mid-air interactions should consider relative movements rather than absolute ones. In this manner, gestures could take place in regions of least effort. Additionally, Hansberger J.T. et al. [6] define supported gestures as gestures that are made while the arms are at rest. They provide evidence for the hypothesis that supported gesture interactions produce significantly less fatigue among the participants compared to mid-air gesture interactions. This is an indication that users might prefer micro gestures over macro gestures because their Consumed Endurance will be lower while their arm is rested on a table.

2.3 Micro Gestures direct manipulation

Liu et al. describe Gunslinger [11], a subtle mid-air interaction technique with a relaxed arms-down position with both hands interacting at the sides of the body. An arms-down posture satisfies relaxed input in terms of arm fatigue.

Chang et al. [3] define micro gestures as gestures performed on the surface of the hand, from the wrist to the fingertips. Micro gestures should be commonly performed and rarely noticeable. These characteristics of micro gestures grant them to be perform naturally in public contexts. Chang et al. gather a set of 16 unique gestures focused on four actions: tap, swipe, circle, and draw. The work from Chang et al. was an important influence for defining the micro gestures set for this prototype.

3 Prototype

To create a test setup, a prototype for the HoloLens and the Leap Motion[2] was developed with the AR-supporting game engine Unity 3D[3] (in the following Unity). The user must select, scale, rotate and move a virtual cube which is projected in the real environment. The cubes are spawned randomly with a fixed seed in the exercise scenes to achieve the same conditions for everyone. In the background, a logging script counts the number of cubes which were successfully selected respectively placed in the target area. The logs include the number of cubes, a list of all events which were triggered, and the timestamp. After each successful action, a short sound gives the user feedback. The exercises were the same for micro and macro gestures.

3.1 Technical Prototype Description: Macro Gestures

3.1.1 Tracking Device

The macro gestures are tracked by built-in sensors in the Microsoft HoloLens. The tracking area is located in front of the headset in the field of view. This requires the user to keep his hand up in mid-air to interact with the cubes.

3.1.2 Tracking Data

Unity offers support for the HoloLens, including remote streaming from the engine to the HoloLens. The open source MixedRealityToolkit was used to implement the macro gestures in Unity.

3.1.3 Interaction with Macro Gestures

The interaction of the macro gestures prototype is built on gaze to target a cube and two gestures of the Microsoft HoloLens: the "air-tap" and the "tap and hold" gesture. To perform the "air-tap", the user must extend his index finger with an approximate distance of 30 cm in front of the HoloLens and tap it against the thumb. The tap and hold gesture is simply maintaining the downward position of the "air-tap". This gesture allows more complex "click and drag" interactions.

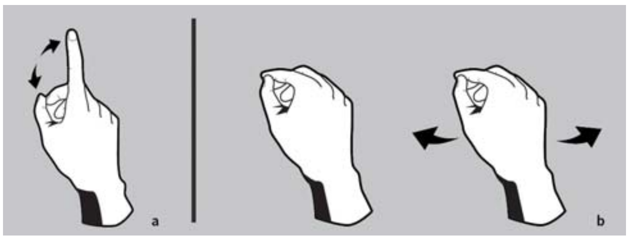

Figure 1: Macro gestures: air-tap (a), tap and hold gesture (b)

[2] https://www.leapmotion.com/
[3] https://unity3d.com

To select a cube, the user must gaze at the cube and perform the "air-tap" gesture. The cube has three different interaction areas which specify one of the three manipulation modes: the corners of the cube for scaling, the edges for rotation, and the surfaces for translation (move). The user must gaze at the area of choice. The "tap and hold" gesture activates the related manipulation mode and, by moving the hand, the cube scales, moves, or rotates with the hand movement. The rotation mode is limited to a specific axis depending on the selected edge. Figure 2 shows the different interaction areas of the cube.

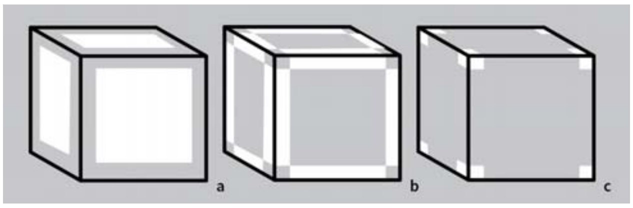

Figure 2: Sensitive interaction areas (white): move (a), rotate (b), and scale (c)

3.1.4 *GUI Elements*

User feedback is provided by the gaze cursor. This enhances the gestural interaction and improves the performance. It reduces the movement time to select a target and a minimization of the error rate [4]. Because of Dover et al. research, a point cursor was included as a standard cursor to indicate the direction and depth of the user's gaze. A point cursor is categorized as a view-fixed GUI element which means that the element stays at a fixed position and orientation within the field of view [4]. Schild et al. explain that view-fixed referencing objects, such a point cursors or lasers, should be positioned spatially as people perform better with a spatial pointing tool than just with a basic cursor. This was realized with the cursors used in the prototype [13].
The macro gestures prototype has four different cursors with three states. The sensitive interaction areas on the cube change the standard cursor on gaze to the scale, rotate, or move cursor (see Figure 5, left). The three different states show if a hand is detected in the field of view and if the "air-tap" gesture is performed (see Figure 3).
In addition, arrows or indication lines around the cube show up while moving, scaling, or rotating the cube. They also indicate the rotational axis in rotation mode. The differences between the GUI of the macro gestures prototype and micro gestures prototype were kept as low as possible to assure the most possible comparability.

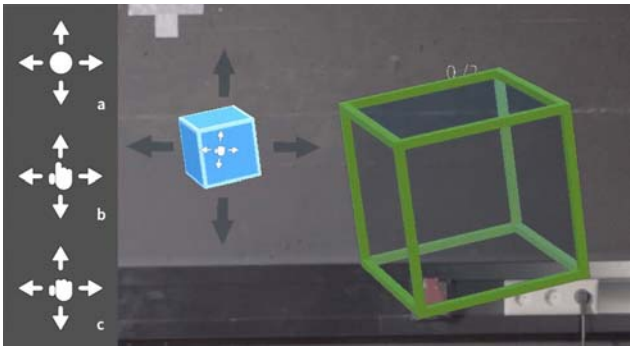

Figure 3: Different cursor states: on gaze (a), on hand detected (b), tap and hold (c)

3.2 Technical Prototype Description: Micro Gestures

3.2.1 *Tracking Device*

The micro gesture prototype uses tracking data from the Leap Motion Controller. It contains three infrared (IR) light emitters and two cameras which measure the finger position by receiving the IR reflections.

3.2.2 *Tracking Data*

Leap Motion offers a constantly updated software development kit (SDK) and the Orion Core Assets package (Version 4.4.0) for Unity. The detector scripts are part of the Leap Motion Orion Core Assets package. Detector scripts offer a simple way of recognizing finger gestures and the finger and palm direction. Every detector triggers an event if all conditions are met. The triggered events are processed by the developed "Gesture Manager" and it causes the desired manipulation of the cube.
To further improve the gesture recognition and make sure the gestures were accomplished purposefully, the "Gesture Manager" implements a gesture activation timer and calculates the average position of the tracked hands over the last three frames (average frame history). This reduces the chance of recognizing a gesture by accident while the user moves their hands and the average frame history smooths tracking errors and hand jittering. The user must hold the gesture for at least 0.5 seconds until the gesture is recognized.

3.2.3 *Interaction with Micro Gestures*

Micro gestures often run into what is called the Midas Touch Problem [9] where everything the user does is interpreted as an interaction. Therefore, it is important that the chosen gesture is unique enough that it will not be accidentally performed.
Chan et al. determined a set of preferred micro gestures when it comes to manipulating a 3D object. These gestures are intuitive and simple with only little movement of at most two

fingers on the palm [3]. The Leap Motion Controller has difficulties tracking this subtle movement. Therefore, the prototype implements five simple, well-known, and clearly recognizable micro gestures. Figure 4 illustrates the five gestures. These gestures activate (Figure 4, a to d) or deactivate (Figure 4, e) the different manipulation modes.

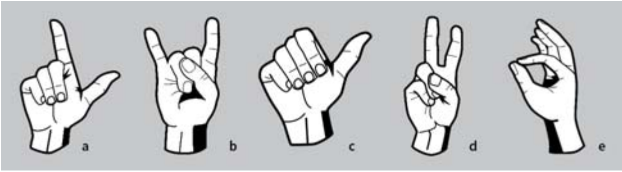

Figure 4: Micro gestures: "select" (a), "scale" (b), "rotate" (c), "move" (d), and "exit" (e)

The manipulation modes are an essential part of the interaction with micro gestures: Whilst a manipulation mode is activated, the only recognized gesture is the "exit" and the "flat hand" gesture. The "flat hand" gesture is the universal gesture to control movement, rotation and scale of the cube while the respective manipulation mode is activated. To prevent the flat hand from overstretching, the fingers must be bended towards the palm to find and retain the resting position of the cube. By bending the fingers further towards the palm, the cube starts to move or rotate along the respective axis direction, bending the fingers towards a flat hand moves or rotates it in the other direction. A slider indicates the resting position of the cube.

The axis can be changed by rotating the hand. The three axes of x, y, and z can be accessed by rotating the hand around the wrist until the palm points to the left, top, or bottom. The value of the angle between the respective axis and the palm must be less than 35 degrees to trigger the change of the axis. This system works for the manipulation mode "move" and "rotate". The manipulation mode "scale" only requires the horizontal flat hand gesture because of the limitation to uniform scale.

Main benefits of the manipulation modes regarding the micro gestures prototype:

- No requirement to hold the gesture ("move", "rotate", "scale" gesture) while manipulating the cube.
- A higher reliability in terms of gesture recognition because the only constantly possible gestures are the "exit" and the "flat hand" gesture.
- A relatively easy approach to control 3-axis manipulation in 3D space with a universal gesture ("flat hand" gesture) which fits to the anatomy of the human hand.

3.2.1 GUI Elements

The micro gesture prototype has a specific cursor for each manipulation mode corresponding to the macro prototype which informs the user about the active mode and if the right gesture has been recognized. A balance slider indicates the resting position of the cube whilst a manipulation mode is active. It helps the user to figure out the right amount of bending the fingers to reach the resting position. The arrows around the selected cube in manipulation mode "move" and "rotate" give feedback about the active axis.

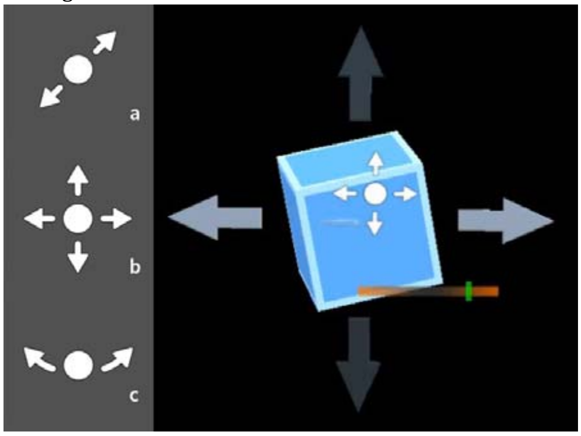

Figure 5: GUI elements: cursor for "scale" (a), "move" (b), and "rotate" (c); arrows to indicate the active axis, and balance slider

4 Study

4.1 Setup

The test was conducted in a darkened room. The user sat on a chair and wore the HoloLens. While they were testing the macro gestures, the user just moved their arm in front of their face. While working with micro gestures, the user lays their arms in a resting position on a table as shown in Figure 6).

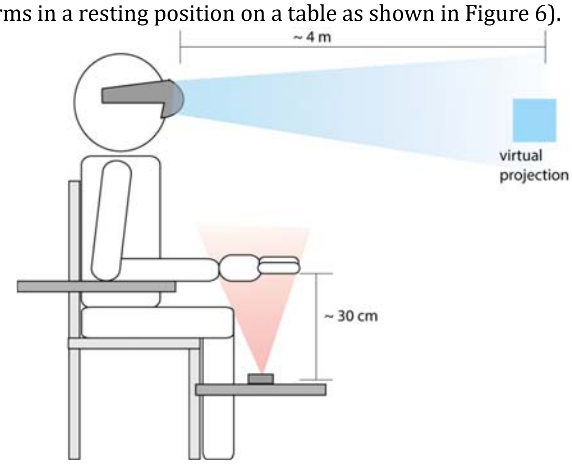

Figure 6: Study setup for the micro gestures

4.2 Hypothesis

This study investigated the efficiency, productivity, and user experience of micro gestures compared to macro gestures with the given prototype. Additionally, psychological effects as cognitive bias were conjectured. Therefore, the following hypotheses were defined:

- H1: When manipulating 3D objects with the HoloLens, the user will be more efficient with micro gestures than with macro gestures.
- H2: When manipulating 3D objects with the HoloLens, the user will be more precise with micro gestures than with macro gestures.
- H3: When manipulating 3D objects with the HoloLens, the user will feel more comfortable with micro gestures than with macro gestures.
- H4: There is a correlation between the preferred gesture set and the starting gesture set.
- H5: There is a correlation between the efficiency and the starting gesture set.
- H6: There is a correlation between the preferred gesture set and the efficiency.
- H7: There is a correlation between the preferred gesture set and the productivity.

The study implemented a within-subject design with all participants testing both micro and macro gesture sets. To balance against possible learning effects, the gesture set sequence was permuted for each participant, gaining two equally distributed groups.

The target group of the user study were right-handed adults. The age of participants ranged from 17 to 55, with an average age of 26 (SD: 7,8) with little or no experience with the Microsoft HoloLens and a high affinity for technology.

4.3 Procedure

For each gesture set participants had to complete four typical 3D operations: select, (uniform) scale, rotate, and move an object in separate exercises. As 3D object, a simple cube was chosen which was coherent for all exercises. The cubes had the same size in all exercises, so the interaction pattern was not influenced by the size of the object like in Piumsomboon's study [12].

Within a time constraint, the objective is to select respectively transform as many cubes as possible which satisfy a given specification, e.g. placing a cube inside a target area. Therefore, a single exercise is divided in three levels: learning phase, easy difficulty level and intermediate difficulty level.

The learning phase allows the participant to get a feeling for the specific gesture without time constraints. After completing two tasks successfully, the first difficulty level starts automatically. The easy and intermediate difficulty levels add a time constraint in which as many tasks as possible must be completed. By increasing the difficulty, there is a smaller margin of error to achieve the objective, while keeping the same time constraint, so the precision of a participant can be measured. The different parameters for all exercises are also depicted in Figure 7.

It should be considered that for each exercise only the required gesture was recognized by the tracking system, so all 3D operations could be observed individually.

At the beginning of each session, the participants were introduced into the basic functionality of the HoloLens by the study moderator. Also, the required gestures for the first gesture set were explained shortly. For the micro gesture set the participants additionally got a short live demonstration on a desktop PC because of its higher complexity. Finally, the participants were encouraged by the study moderator to think aloud during all exercises.

Before each exercise, the study moderator explained the required gesture for the given 3D operation again. In the learning phase, the participants were also allowed to ask questions and get help by the study moderator. Additionally, there were posters to support the participants by displaying illustrated hand figures representing all available gestures. After completing all exercises for one gesture set, the participants had to answer a user questionnaire including the standardized User Experience Questionnaire (UEQ) [10], general questions about the Microsoft HoloLens and socio-demographic details (e.g. age, gender). The whole procedure was then repeated for the second gesture set.

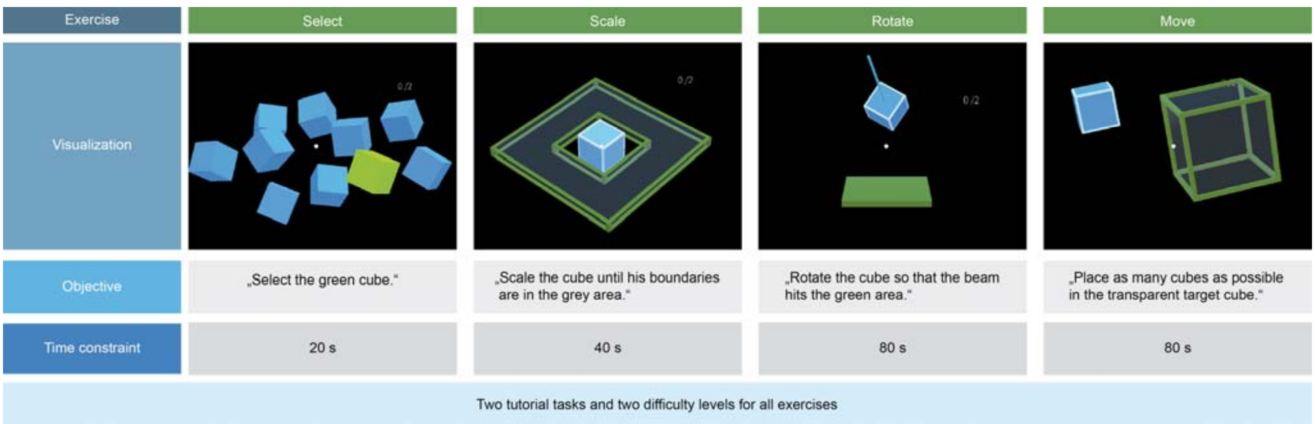

Figure 7: Parameter settings for all exercises in the full study

4.4 Pilot Study

A pilot study was conducted with three participants (2 male, 1 female) to determine the study procedure. Based on the pilot study, the time constraints were adjusted for each exercise to keep a better balance between them. Secondly, a previously planned third difficulty level for each exercise was removed and replaced by an intermediate difficulty level. This was necessary as the participants were not able to learn the required accuracy in the given study time frame. Finally, the sequence of exercises was reordered to allow a better learning experience of the given gesture set by ordering them according to the required axes for completing a task ("scale": 1 axis; "rotate": 2 axes; "move": 3 axes). See also Table 1.
Additionally, the general usability of the prototype was improved by removing unnecessary obstructions e.g. reducing the activation time of micro gestures and increasing the selection area for rotation and scale operations with macro gestures.

Pilot Study	Full Study
Select	Select
Move	Scale
Rotate	Rotate
Scale	Move

Table 1: Exercise sequence before and after the pilot study

4.5 Participants

23 volunteers participated in the study (14 male, 9 female). The ages ranged from 17 to 55 years (mean = 26.0, SD = 7.9), mainly with university background (18 students, 1 postgraduate, 2 full-time employed, 2 others). The participants also showed high interest in technology: they chose a 6.3 on average (7-Likert scale, SD = 0.7) when asked about their technological affinity in the user questionnaire.

4.6 Measurements

As defined in the hypotheses, the study had to measure the efficiency, productivity, and user experience for a given gesture set. This was achieved by logging the event data of the prototype (e.g. gesture activations and completed tasks). To evaluate the user experience, the user questionnaire was used and assisted by video and screen recordings of each session.

To measure productivity and efficiency, the terms were defined as follows:

- Efficiency is the total amount of completed tasks within the time constraint of a difficulty level.
- Productivity is the efficiency divided by the amount of measured gesture activations.

5 Results

First, the difficulty levels of each exercise were compared. Three values were significant in a paired t-test: in the "move" and the "rotate" exercise for micro gestures, the users manipulated less cubes in difficulty one than in difficulty two ($p_{moveMicro} = 0.02$; $p_{rotateMicro} = 0.002$). In the exercise "move" for macro gestures, users moved significantly more cubes into the target area in difficulty level 2 ($p_{moveMacro} = 0.002$).
Due to those results, a learning process can be suspected. This is the reason why in the following paragraphs only results of difficulty level 2 are compared.
As can be seen in Figure 8, multiple significant effects in the efficiency can be determined (paired t-test, $p < 0.05$). In the "move" exercise, macro gestures were more efficient, and the difference is highly significant ($p_{move} = 0$). With macro gestures, the user moved 3.7 cubes on average (SD 1.05), with micro gestures 1.1 (SD 0.9). In both exercises "rotation" and "scale", micro gestures were more efficient ($p_{rotate} = 0.014$; $p_{scale} = 0$); users rotated 2.5 cubes on average (SD 1.95) with the macro gesture set, but 3.7 with micro gestures (SD 1.92). In the "scale" exercise, the difference is clearer: 2.2 cubes with macro gestures (SD 1.91) vs. 6.26 cubes with micro gestures (SD: 1.60). The p-value for the "select" exercise is $p_{select} = 0.73$. Overall, 78 % of the participants were more efficient with micro than with macro gestures.

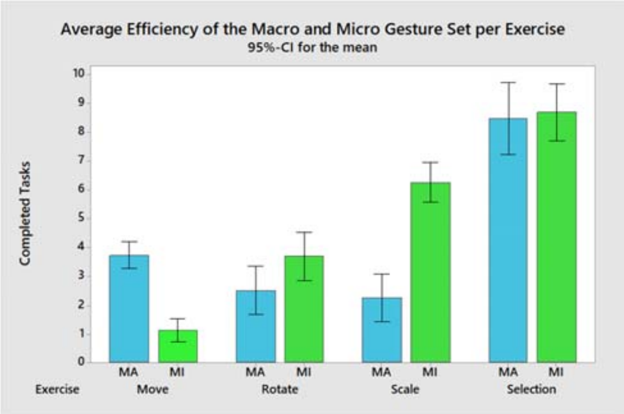

Figure 8: Average efficiency of both gesture sets

Productivity values are scaled between 0 (not productive) and 1 (very productive). As shown in Figure 9, the average productivity in "move" is higher with micro gestures, but not significant ($p_{move} = 0.45$). The average productivity in "rotate" and "scale" however is significantly higher with micro gestures. The average productivity values are $\text{Productivity}_{\text{rotateMacro}} = 0.34$ (SD 0.16) and $\text{Productivity}_{\text{rotateMicro}} = 0.73$ (SD 0.28), respectively $\text{Productivity}_{\text{scaleMacro}} = 0.58$ (SD 0.41) and $\text{Productivity}_{\text{scaleMicro}} = 0.93$ (SD 0.12). Their associated p-values are $p = 0$. The productivity values in the "select" exercise were very similar to each other ($\text{Productivity}_{\text{selectMacro}} = 0.99$ (SD 0.03) vs. $\text{Productivity}_{\text{selectMicro}} = 0.97$ (SD 0.07); $p_{\text{select}} = 0.08$). The values for "move" and "select" not considered significant. 83 % of the participants had a higher productivity value with micro gestures.

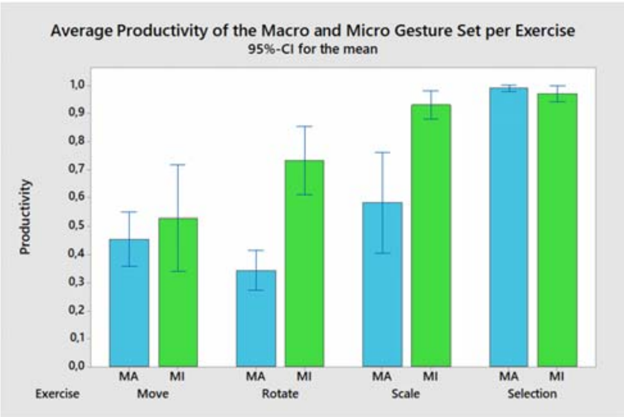

Figure 9: Average productivity values of both gesture sets

In Figure 10, the user experience values are shown. A paired t-test showed that there is only a significant difference in the dimension novelty (p=0.036), so micro gestures were considered more creative and innovative. The t-test results for all the other dimensions did not show any significantly relevant difference.

During the test, many participants said that their arms fatigue during the usage of macro gestures. Some users rested their arm partly unconsciously on the table next to them to minimize the tiredness. While using micro gestures, some participants said that turning their palm upwards was exhausting and inconvenient. Although these impressions influenced their user experience, the measured values of the UEQ did not lead to relevant and significant results.

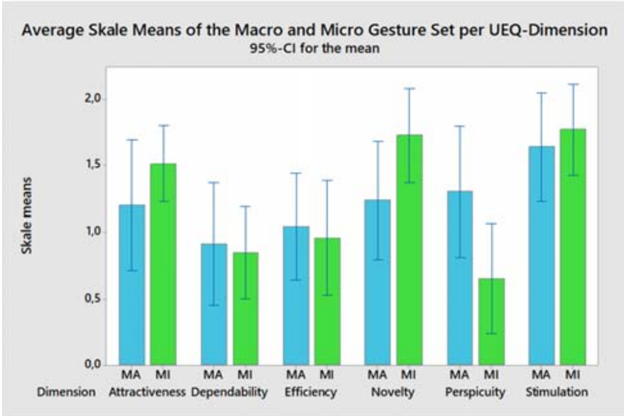

Figure 10: Scale means for each dimension of the UEQ

The starting gesture set had no significant influence on the preferred gesture set. 12 of 23 participants started with the macro gesture set. By using a contingency table, it can be seen that only 40 % of them answered the question "If you had to choose one gesture set, what would it be?" with "macro gestures". In total, 57 % of all participants answered the question after their preferred gesture set with "micro". 38 % of the participants who indicated micro gestures as their preferred set started with the micro gesture set.

Only 1 out of 12 who started with the macro gesture set was more efficient with it. 39 % of the participants who were more efficient with micro gestures, started with this set.

Regarding the preferred gesture set, the efficiency had no significant influence as well. 80 % of the participants (4 out of 5) who were more efficient with macro gestures, answered this question with "macro" (see Table 2).

The same effect occurs when relating productivity and preferred gesture set. 75 % of the participants (3 out of 4) who were more productive with macro gestures answered this question with "macro". 92 % of the participants who indicated micro gestures as their preferred gesture set were more efficient and more productive with it. 63 % of the people who were more productive with micro gestures chose micro gestures as their preferred gesture set.

A chi-squared test shows that none of these values is significant.

	Preferred Gesture Set Macro	Preferred Gesture Set Micro	Sum
More Efficient with Macro	4 80 % 40 %	1 20 % 8 %	5 100 % 22 %
More Efficient with Micro	6 33 % 60 %	12 67 % 92 %	18 100 % 78 %
Sum	10 43 % 100 %	13 57 % 100 %	23 100 % 100 %

Table 2: Table 2: Relation efficiency - preferred gesture set (Content: absolute number, fraction of line, fraction of column)

6 Discussion

The comparison of the two difficulty levels leads to the conclusion that in the "move" and "rotate" exercise for micro gestures it is harder for users to work more exact. Only in the "move" exercise for the macro gesture set, the users moved more cubes into the target area in difficulty level 2. There is a presumption that especially in this exercise the learning progress was saturated in the first difficulty level.

The hypothesis about the more efficient gesture set (H1) can only be answered for the exercises "rotate", "scale" (both micro gestures) and "move" (macro gestures). The big difference in the exercise "move" can be explained with the 3D movement of the arm in front of the user. It was not necessary to abstract the movement to a switch of axes. The cube could be moved almost like a real object to all three dimensions at the same time (so called "natural mapping").

The similarity in efficiency and productivity in the "selection" exercise is strongly connected to the similar way of choosing the colored cube: in both cases, the user first had to move their head towards the right cube, and second do a gesture (either mid-air or rested) to confirm his decision. Especially in this exercise, it's very likely that the user had to get used to the hand-head coordination first but learned it very quickly.

Overall, participants were more productive with micro gestures but hypothesis H2 can only be confirmed for the exercises "scale" and "rotate" because the p-values are significant in those exercises. A reason for this could be that the hand tracking was more reliable than the ability of the user to correctly select the sensitive interaction area with gaze and move the hand into the correct direction.

The hypothesis about the user experience (H3) can neither be confirmed nor refuted. The fact that although most participants were more productive and efficient with micro gestures in general but did not choose it as preferred gesture set, leads to the conclusion that there are more influences for preferences than just efficiency or productivity. One option why people choose macro gestures could be that they are easier to remember because only one gesture is needed, and it is not necessary to think in a coordinate system and axes.

During the test, many participants had problems keeping their visual focus at one point to choose the right edge for a manipulation with macro gestures. The connection between head and arm was described as uncomfortable and unusual. Furthermore, some of the users said that another feedback system could help them to earlier recognize the sensitive areas.

The start gesture set did not influence the preference (H4). There is hardly a difference between the gesture sets which leads to the refutation of the hypothesis.

The start gesture set did not influence the efficiency (H5) either. Probably, the gesture sets were different enough from each other. Most of the users were not able to create knowledge enough to translate the cognitive model from the first to the next run.

Although micro gestures were more efficient in average and significantly more efficient in the exercises "rotate" and "scale", only 67 % of the users chose this gesture set as their preferred gesture set. This shows that there is no connection between the efficiency and the preferred gesture set (H6), so the hypothesis can be refuted.

Not only efficiency but also productivity has no influence on the decision about the preferred gesture set. (H7).

7 Limitations

7.1 Gesture Set

This user study allows statements about the tested gestures. It is conceivable that with other gestures the results could be different. A big influence on the user experience, efficiency, and productivity was the tournament of the hand wrist. To make the tournament of the hand palm easier for the user, the position of the Leap Motion and the sitting position could be varied.

7.2 Combination of Gestures

In this research, all gestures were analyzed individually, e.g. the user only had to use either the "rotate" or the "move" gesture. There was no need to change the manipulation modus within one exercise. To get a complete picture of the efficiency and productivity of the gesture sets, it is necessary to combine all the single gestures in a more complex exercise. The change between the gestures and axes offers new challenges for a user.

7.3 Learning effect

The test duration for one gesture set was brief (less than 30 minutes). There was little time to get used to the system, such gestures, the visualization, and the user interface. Another test over a longer familiarization time could give more information about the learning process for gestures and the influence on a preferred gesture set. Especially the tracking area of the finger in front of the HoloLens needs to be learned. In this context, one of the main problems of macro gestures is the constant tension in the shoulders and arms to hold the arm in front of the HoloLens. After having enough time to find out how big the tracking area is, the user could better assess where they can hold the arm in a more relaxed position. This could lower the error rate and higher the productivity because the user does not leave the tracking area often. After more time for learning the gesture sets, users could get more used to micro gestures and their complexity as well. This might lead to a better user experience. This theory is supported by a superficial comparison of the test results between the participants of the study and the developers who have worked with the gesture sets for several weeks.

7.4 Technical Limitations

For a successful hand tracking, the movements of the hands need to be relatively big. This was the main influence on the tested gesture set. If smaller gestures could get recognized better, the user experience could increase. Nevertheless, the Midas Touch Problem could become more important with smaller gestures.

Another technical limitation is the size of the tracking area of the HoloLens. If the tracking area was bigger and the user could rest the arm occasionally during repetitive exercises the user experience might be higher for macro gestures.

7.4 Graphical User Interface

To gain only information about the properties of the gesture sets and not about the visual feedback system, the GUI elements in this prototype are designed as similar as possible. To make macro gestures more efficient, especially in the exercises “rotate” and “scale”, a visual representation of the sensitive areas could help the user enormously. With another user interface, the comparison between micro and macro gestures could lead to different results.

8 Future Work

This paper provides a starting point and blueprint procedure for a profound research of macro and micro gestures in comparison. In future studies, the parameters shown in the limitations should be varied, and therefore allow to determine the influence of learning effects, gestures and interface implementations. It would allow to provide a full picture of macro in relation to micro gestures in Augmented Reality.

9 Conclusion

Gestures are an interactive input method for Augmented Reality systems which becomes more and more important. Macro gestures which are used with head-mounted displays like the Microsoft HoloLens can cause fatigue and let the user feel uncomfortable when using them in public. Therefore, micro gestures became more popular over the last few years. Micro gestures use small finger and hand wrist movements. Because of minimal or no movements in depth and the concept of using three axes separately, they may appear unintuitive and harder to remember. However, they can outperform the more intuitive macro gestures in difficult tasks, suggesting a possible correlation between task complexity and needed interface complexity.

As this research has demonstrated, the implemented micro gestures are more efficient and productive for scaling and rotating 3D objects in Augmented Reality than macro gestures. Only move operations were more efficient with macro gestures because of the translation of the natural spatial interaction to the AR environment. The complexity of micro gestures combined with the short learning phase could be an explanation why some participants preferred macro gestures despite their worse test results.

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