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Abstract

Mobile applications offer great possibilities to the aging population but older adults face accessibility problems when using devices equipped with touchscreen. In order to respond to older users' special needs, it is necessary to support older users during tactile interaction to reduce error rates. The aim of this study is to evaluate the effects of the accuracy requirements for drag-and-drop interaction. 24 able-bodied older adults with different profiles (aged 65 to 86 years old, with corrected and not corrected eyesight, normal and low dexterity, different levels of education, different experience of use of computers and touchscreen) executed a series of tactile puzzle games on smartphone and tablet, with pen and fingers. We evaluate the number of errors for two levels of accuracy required for positioning the puzzle pieces: 95% (higher) and 80% (lower). Older adults made fewer errors of accuracy during lower accuracy levels and consequently fewer supplementary gestures for positioning the targets. Besides, lowering the accuracy requirement was an effective support for interaction because it also reduced the effects of users' profiles, improving the accessibility for people with no experience of use of computers.

Keywords: Touchscreen;elderly; drag-and-drop; errors; accuracy; accessibility

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1. Introduction

Mobile devices are light weighted and often equipped with touchscreen, offering great possibilities of design for applications destined to meet the needs and expectancies of the older populations. Several applications have been developed to improve well-being, enhance social interaction[1] and help older adults to learn interaction[2]. Tactile interaction has been recommended for older people because direct interaction on the display screen demands less hand eye-coordination and requires less attentional and cognitive load[3]. However, accessibility issues are still preventing older adults to benefit of mobile devices and applications. The aging effects on perceptual, motor and cognitive systems are an individual process, making older adults a heterogeneous group. Besides, the abilities and difficulties of older users are also related to their health conditions and their prior experiences with technologies[4].

Previous studies about the accessibility of touchscreen have detected the common errors older adults make during interaction. Errors can be related to the device[5], to the graphical user interface[6], to the interaction techniques[7] or to the users' abilities[8,9]. Most of the studies provide substantial design recommendations[10]. But only few studies have designed some support to help older adults with difficulties to accomplish interaction. Support for interaction has been designed by means of adapted gestures of interaction[11,12], adapted interfaces[6,13] or techniques of assistance[14,15].

The Puzzle Touch system is a web-based application being developed to help novice older adults to discover touchscreen devices and learn tactile interaction. The present study aims to improve the accessibility of drag-and-drop interaction for executing tactile puzzle games. As a support for tactile interaction of older users, we evaluate the effects of two accuracy requirements for positioning the targets.

Lowering the accuracy requirements during tactile interaction should reduce the number of errors. In order to test our hypothesis, we conducted a study with 24 older adults (65 to 86 years old). They executed a series of tactile puzzle games on smartphone and tablet, with pen and fingers. Additionally, we evaluate the effects of the user's profiles on interaction such as age, gender, visual and motor limitations, education and previous experience with computers and touchscreen.

The remainder of this paper is organized as follows. Section 2 presents the related work on errors of interaction by older adults and design of support techniques. Section 3 describes the design of Puzzle Touch system. Section 4 specifies the parameters of the interactive system as they were set for the experiment and the procedures. Results are detailed in Section 5, followed by discussion in section 6 and conclusion in section 7.

2. Related work

Error rates are commonly used for evaluating performances on human-computer interaction studies. Some errors of interaction are related to the device, e.g. physical controls and buttons that are difficult to identify and activate[5,16]. Errors can also be related to the graphical user interface, e.g. lack of explicit display for current state[7], keyboard layout[8] or small targets[7]. Concerning the interaction techniques, users had difficulties to accomplish some gestures of interaction, e.g. zooming without panning[7], rotating or resizing during multi-touch interaction[17]. In addition to that, some errors are related to the users' abilities, e.g. substitution errors during text entry tasks due to hand tremor[8], missing small icons because of low attentional skill[9].

The inconvenience of direct interaction is that touching the screen with finger or pen leads to the occlusion of a part of the screen. In addition to that gestural interaction demands high dexterity of the user.

The causes of some errors are due to the combination of the users' abilities and the interaction techniques. Fisk et al. (2009) has defined "slips" as an unintentional activation of a control[18]. Moffat and McGrenere (2007) have detected slipping errors during target acquisition tasks with pen[19], when the pen lands on the target but slips and activates the adjacent target. Nicolau and Jorge (2012) have identified slipping errors during typing tasks with the finger, when low dexterity caused substitution errors[8]. Slipping errors can have severe consequences during real tasks, e.g. dialing an erroneous phone number. Besides, recovering from errors represent a significant workload for older adults, especially for novice users who need to develop a strategy to restore the previous state, e.g. stop the calling, erase the incorrect number, etc.

Lack of accuracy of the gesture of interaction causes slipping errors. Some studies have designed interaction techniques that improve the accuracy of the gestures on adapted graphical user interfaces. Ramos et al (2007) have designed *Pointing Lenses* to help target acquisition with pen interaction on touchscreen. The cursor area is presented slightly aside and magnified. The target is selected inside the lens. Moffatt and McGrenere (2010) designed *Steadied-Buble*, a technique that modifies the cursor area and then blocks the cursor position on a location threshold, avoiding slipping errors for pen based interaction[14]. Expanding targets widths and modifying the cursor properties can be applied to web-based interaction. Watanabe et al. (2011) designed the *Link-Offset-Scale* technique to help link selection with pen and finger on touchscreen devices[20].

The studies mentioned above addressed lack of accuracy for tapping tasks. Mertens and Jochems (2010) have designed *Trabing*, a technique to support target acquisition and text entry for older users with tremor[11]. The user slides the finger towards the target and validates the selection releasing the screen. The continuous contact of the finger sliding on the screen diminishes the oscillation and improves the accuracy. Wacharamanotham (2011) compared *Swabbing* to tapping and he demonstrated reduced error rates[12].

Some applications don't allow the modification of the layout of the graphical user interface. When many targets are presented on the screen, expanding targets would disturb the display of adjacent items. The same way, modifying the cursor properties would affect the accuracy of the gesture on encumbered layouts.

A combination of the adaptation of targets and cursor properties could be possible without modifying the layout display. Reducing the accuracy requirements would be equivalent, in a certain way, to virtually expanding the target. Concerning the drag-and-drop interaction, the cursor area can be expanded to the size of the object that is being dragged. Besides, the acquisition criteria can be verified at the moment when the user releases the screen (drop). We try to apply this concept to the Puzzle Touch system, in order to evaluate this possibility as a support technique for improving the accessibility of tactile puzzle games.

3. The design of the Puzzle Touch system

The Puzzle Touch system is a web based application aiming to help older adults to learn and discover tactile interaction and touchscreen devices. Tactile puzzle games are a familiar activity, arousing the interest of reluctant older adults and facilitating the inclusion of novice users as participants for the experiences.

The grid of targets is displayed on the top of the screen. For a twelve pieces puzzle game, the grid is composed of three lines and four columns; each emplacement corresponds to one of the puzzle pieces randomly placed on the bottom of the screen. A puzzle piece and its target are exactly the same size. Once the user touches a puzzle piece with pen or finger, the piece follows the movement as long as there is a contact with the screen (drag). When the user releases the screen, the piece stops (drop). The positioning is verified when the piece is dropped. If the piece is correctly placed, covering its emplacement on the grid and meeting the accuracy requirements, there is a visual feedback (the piece flashes) and cannot be moved again. When the dropped piece doesn't meet the accuracy requirement, a supplementary movement is necessary to adjust its positioning. The game is over when all the puzzle pieces are correctly placed.

The system is being developed with HTML5, CSS3 and JavaScript following the current accessibility specifications for mobile web[21]. It includes a series of tactile puzzle games displayed on web browser application installed on mobile devices. The puzzle games are responsive, fitting the tablet or the smartphone touchscreen on portrait and landscape orientation. Several parameters of the game can be set to evaluate and facilitate user's interaction, such as number and size of targets, accuracy requirements for positioning the puzzle pieces, feedback and the choice of images.

Images of colored postcard representing monuments of the city subjects live in have been used for generating the puzzle games. For the following experience, devices will be blocked on portrait orientation. The image is presented as a watermark on the background for the grid to reduce the cognitive workload of the task, so participants can be focused on the accuracy of their gestures.

An empirical observation of our previous study allowed the identification of errors related to the device, the interaction technique and the users' abilities[16]. By consequence, we modified the parameters of the application for preventing errors related to the single touch interaction.

4. Methodology

The aim of the present study is to evaluate the effects of the accuracy requirements for positioning targets on touchscreen. This study extends a previous work on the evaluation of the accuracy of drag-and-drop gestures for older adults[22]. Concerning the accessibility of the Puzzle Touch system, two hypotheses are formulated:

H1: Lower accuracy requirements reduce the number of errors of accuracy during drag-and-drop interaction. We expect that lower accuracy requirements affects positively older adults' performances during tactile interaction, supporting the gesture of interaction and improving accessibility of the tactile puzzle games.

H2: Lower accuracy requirements reduce the effects of user's profile. The related work has reported that user's abilities can affects the performances of interaction. Hence, we will also evaluate effects of users' profile (gender, age, education, dexterity, sight and previous experience with computers and touchscreen devices). If these effects are verified, we expect that improving accessibility by reducing the accuracy requirements will facilitate the interaction for the groups of users who needs support for preventing errors of accuracy.

4.1. Settings of the interactive system

For the present study, the interactive system has been set to generate twelve pieces puzzle games. This version of the game is multi-touch, many puzzle pieces can be moved at the same time. The consequence of the activation of the multi-touch is the possibility of prioritizing the target interaction zone. Every area of the game play is now independent: as the puzzle pieces are dragged, touching the empty zones around targets don't interfere on the current position of other pieces. By doing so, we can prevent errors related to the secondary touches, i.e. when the user places the palm of the hand or another finger on the screen inadvertently - for resting or for better controlling the movements of the fingers - it doesn't disturb the movement of the puzzle pieces.

In order to evaluate the effects of accuracy requirements, two levels have been set for the game. The lower accuracy level requires dropped pieces to be covering at least 80% of their corresponding target. If this condition is met, the piece is magnetized to fits it's exact position and cannot be removed. The higher level is set to 95%.

4.2. Task

Subjects should execute drag-and-drop interaction. The main task is dragging the puzzle pieces, randomly displayed below the grid, to their corresponding emplacement on the grid (target). For each game, the task is accomplished when the twelve pieces of the puzzle are correctly placed, recomposing the original image.

4.3. Procedures

Volunteers were recruited during demonstration meetings. Before the experiment, participants gave their formal consent and executed some familiarization puzzle games with both screen sizes and both interaction techniques until they understand and are able to accomplish the interaction.

Then we assessed user's profiles information through questionnaires including age, gender, education, questions about frequency of use of computers and touchscreen devices. In the questionnaire, they are asked about dexterity limitations or any injury of hands or upper limb that could interfere on the accuracy of the gestures. After that they passed an eyesight control. Three applications for eyesight tests were installed on the smartphone (healthcare4mobile, https://play.google.com/store/apps/developer?id=healthcare4mobile): color perception, central vision acuity and contrast sensitivity. For the tests, the screen was hold vertically about 30 cm in front of the subjects' faces. Subjects who wore glasses were told to keep them. The scores of the three tests allowed the identification of subjects with insufficient eyesight correction.

The experiment lasts about 30 minutes, during this time each subject executed eight tactile puzzle games on smartphone and tablet with pen and fingers so different situations of use and screen sizes can be evaluated. The order of the devices and interaction techniques was counter-balanced. Participants played first the games on lower accuracy levels, then the higher accuracy ones. They were told to play the games with accuracy. Further information is described on our previous study[22].

4.4. Material

A smartphone and a tablet, both allowing interaction with pen and finger, have been chosen for this experiment. The smartphone was a Galaxy Note II with a WXGA 1280x720 Super AMOLED 5.5 inches touchscreen. The tablet was a Galaxy Note 10.1 with a WXGA 1280x800 LCD 10.1 inches screen tablet touchscreen.

4.5. Measures

Two independent variables are treated on the present study: the accuracy requirements and the subjects' profile. There are two accuracy requirements: low or high levels of accuracy. The subjects' profile comprises seven characteristics: age, gender, education, dexterity, sight, use of computers and use of touchscreen.

One dependent variable is evaluated: the ratio between the total numbers of errors of accuracy made during a game and the number of targets - REA. Errors of accuracy are counted when a piece is dropped on the grid,covering at least 50% of its correspondent emplacement but the accuracy requirement is not met, so the piece must be readjusted. We fixed this initial requirement of 50% covering because it indicates that the user has found and reached the correct target. The number of errors of accuracy measures the number of supplementary moves for positioning a target accurately.

Time for completing the game, time and movement and the coordinates of the touches have been registered for further evaluation. When a piece is dropped on an incorrect emplacement on the grid, it can be considered as a part of the strategy of the user to accomplish the game. The piece should be moved again until matching its correspondent target. This manipulation has been registered to be evaluated later.

4.6. Participants

24 able-bodied older adults (range 65-86, mean 74.25, SD= 5.70) participated of the experience. Subjects have been divided into groups according to their profiles for the following characteristics for the statistical analysis.

Four age-groups have been set:

- 5 subjects are aged 65 to 69 years old,
- 10 are aged 70 to 74 years old,
- 3 are aged 75 to79 years old,
- 5 are aged 80 or older.

Two groups for have been set by gender:

- 16 women,
- 8 men.

Results of eyesight control have been used to divide subjects into two groups:

- 19 subjects had sufficient correction and
- 5 had insufficient correction.

The groups below were formed based on the information assessed through the questionnaires.

Two groups have been set according to the level of education:

- 13 subjects did primary school,
- 11 completed higher education.

Two groups have been set for dexterity:

- Normal included 15 subjects did not report any dexterity problems.
- Low dexterity included the 9 subjects who reported some dexterity difficulties because of common motor control decline related to the normal aging such as arthrosis (3 subjects), ancient injuries affecting fingers or hands movement (3 subjects) or sensibility (1 subject), light tremor (2 subjects).

Two groups of subjects according to their use of computers:

- 16 reported having a computer and using it regularly (almost every day or at least once a month),
- 8 reported not having a computer and rarely using one.

Two groups of subjects according to their use of touchscreen:

- 8 reported having a touchscreen device (smartphone or tablet) and using it regularly (almost every day or at least once a week),
- 16 reported no possession of touchscreen devices and no experience of use (never or rarely using it).

The subject's profiles are detailed on Table 1.

Table 1 Subjects' profiles

Id	Age	Gender	Education	Dexterity	Sight	Use of computer*	Use of touchscreen*
P1	65	Male	Higher	Normal	Corrected	5	5
P2	65	Female	Primary	Normal	Corrected	5	1
P3	66	Female	Higher	Normal	Corrected	5	1
P4	68	Male	Higher	Normal	Corrected	5	1
P5	69	Female	Higher	Normal	Corrected	1	1
P6	70	Male	Primary	Low (tremor)	Not corrected	1	1
P7	70	Female	Higher	Low (finger)	Corrected	5	1
P8	71	Male	Primary	Normal	Corrected	1	1
P9	72	Female	Higher	Low (sensibility)	Corrected	5	1
P10	73	Female	Primary	Low (arthrosis)	Corrected	1	1
P11	73	Female	Primary	Low (finger)	Corrected	2	5
P12	74	Female	Higher	Low (arthrosis)	Corrected	4	1
P13	74	Female	Higher	Low (arthrosis)	Corrected	5	1
P14	74	Female	Higher	Low (arthrosis)	Corrected	4	4
P15	74	Male	Primary	Normal	Corrected	5	2
P16	77	Male	Primary	Normal	Corrected	5	5
P17	77	Female	Primary	Normal	Not corrected	1	1
P18	78	Male	Higher	Normal	Not corrected	5	5
P19	80	Female	Primary	Normal	Corrected	5	5
P20	80	Female	Primary	Normal	Corrected	1	1
P21	82	Female	Primary	Low (hands)	Corrected	3	1
P22	82	Male	Higher	Normal	Corrected	5	1
P23	82	Female	Primary	Low (tremor)	Not corrected	1	1
P24	86	Female	Primary	Normal	Not corrected	5	5

*Frequency of use: 1) I never use it, 2) I have already used it or I rarely use it, 3) I use it at least once a month, 4) At least once a week, 5) Every day or almost every day

4.7. Statistical analysis

According to the results of Shapiro-Wilk test, REA is not normally distributed (all games W= 0.79, p-value= 2.2e-15; high accuracy: W= 0.9, p-value= 2.67e-06; low accuracy: W= 0.82, p-value= 1.7e-09). REA data distribution curve is skewed to the left. So we detailed the median values to indicate tendencies and inter-quartile values to indicate deviations. Consequently, Wilcoxon signed rank test has been used to look for significant effects of accuracy requirements. Kruskal-Wallis test has been used to look for age effects (four age-ranges) and Mann-Whitney test has been used to look for significant effects of participants' profile (gender, sight, dexterity, education, use of computers, use of touchscreen). When the two accuracy levels are treated separately, a Bonferroni correction has been applied, setting the p-value to 0.025.

5. Results

There is a significant effect of accuracy requirements on REA for all subjects (Z= -8.34, V= 45.5, p-value < 2.2e-16). Table 2 summarizes the significant effects of user's profiles for all games and then for different accuracy requirements.

There is no significant effects of participants profiles on REA for gender (Z= 4.68, W= 3609, p-value= 0.18), educational level (Z= 6.27, W= 4045, p-value= 0.167) or use of touchscreen (Z= 7.60, W= 4406.5, p-value= 0.39).

There are significant effects of age on REA (chi-squared= 15.84, df= 3, p-value= 0.001), sight on REA (Z= -1.95, W= 1795, p-value= 6.7e-05), dexterity (Z= 10.31, W= 5148, p-value= 0.031) and use of computers (Z= 9.46, W= 4915.5, p-value= 0.02).

Consequently, we search the effects of users' profiles on the different accuracy requirements.

For the higher accuracy levels there was no significant effects of gender (Z= 2.90, W= 871, p-value = 0.24), dexterity (Z= 7.34, W= 1303.5, p-value= 0.11), education (Z= 3.28, W= 907.5, p-value = 0.08) and use of touchscreen (Z= 5.32, W= 1106.5, p-value= 0.52). Significant effects were found for age (chi-squared= 19.33, df= 3, p-value= 0.0002), sight (Z= -2.94, W= 301, p-value= 3.5e-05) and use of computer (Z= 8.30, W= 1397.5, p-value= 0.004).

For the lower accuracy levels there was no significant effects of gender (Z= 2.48, W= 830, p-value= 0.13), dexterity (Z= 8.02, W= 1369.5, p-value= 0.03), education (Z= 4.76, W= 1052, p-value= 0.50), use of computer (Z= 5.96, W= 1168.5, p-value= 0.26) and use of touchscreen (Z= 5.99, W= 1172.5, p-value= 0.25). Significant effects were found for age (chi-squared= 11.77, df= 3, p-value= 0.008) and sight (Z= -1.80, W= 412.5, p-value= 0.002).

Table 2 Effects of users profiles on REA and difference of gaps between higher and lower accuracy levels

Users profile effects on REA	Age	Gender	Sight	Dexterity	Education	Use of computer	Use of touchscreen
Significant effect for all games	**0.001***	0.17	**6.7e-05***	**0.03***	0.16	**0.02***	0.39
Significant effect on higher levels	**0.0002****	0.24	**3.5e-05****	0.11	0.08	**0.004****	0.50
Significant effect on lower levels	**0.008****	0.13	**0.002****	0.03	0.50	0.26	0.25

* Significant effects p<0.05; **Significant effects p<0.025

Median values for REA by age range are as follows: 0.29 for subjects aged 65 to 69 (IQR= 0.5), 0.5 for subjects aged 70 to 74 (IQR= 1.13), 0.83 for subjects aged 75 to 79 (IQR= 1.16) and 0.63 seconds for subjects aged 80 or older (IQR= 1.65). The variability increases with the age. Subjects aged 80 years old or older made fewer errors of accuracy than subjects aged 75 to 79.

There are significant effects of sight on REA (Z= -1.95, W= 1795, p-value= 6.69e-05). Subjects with insufficient eyesight correction made more errors of accuracy, median REA for this group of subjects is 1.42 (IQR=1.94) while subjects with sufficient eyesight correction made 0.42 (IQR=0.85) errors of accuracy for positioning each target.

There are significant effects of dexterity on REA (Z= 10.31, W= 5148, p-value= 0.03). Subjects who reported dexterity problems had a higher REA, median of 0.67 (IQR= 1.41), than subjects with normal dexterity (median REA 0.42, IQR= 0.95).

There are significant effects of use of computers on REA (Z= 9.46, W= 4915.5, p-value= 0.02). Subjects who use computers had a lower REA, median of 0.42 (IQR= 0.93) than subjects who don't use a computer, whose median REA was 0.79 (IQR= 1.54).

Table 3 describes REA for all subjects and four age groups for all games, low and high accuracy levels. Table 4 describes REA for the groups of users according to their profiles: sight, dexterity and use of computer.

Table 3 REA for age groups and all subjects for all games and two accuracy levels (medians and inter-quartiles)

Users profile effects on REA	65-69	70-74	75-79	80 or older	All subjects
All games	0.29 (0.50)	0.50 (1.13)	0.83 (1.17)	0.63 (1.65)	0.50 (1.17)
Higher levels	0.58 (0.60)	1.33 (1.96)	1.71 (1.48)	1.88 (2.04)	1.33 (1.83)
Lower levels	0.08 (0.27)	0.25 (0.29)	0.50 (0.46)	0.17 (0.38)	0.25 (0.33)

Table 4 REA for groups of users (sight, dexterity and use of computer) for all games and two accuracy levels (median and inter-quartiles)

Users profile effects on REA	Corrected sight	Not corrected sight	Normal dexterity	Low dexterity	Use computer	Do not use computer
All games	0.42 (0.85)	1.41 (1.93)	0.42 (0.96)	0.67 (1.42)	0.42 (0.93)	0.79 (1.54)
Higher levels	0.96 (1.29)	2.45 (1.88)	1.17 (1.42)	1.58 (1.67)	1.04 (1.44)	1.92 (2.33)
Lower levels	0.17 (0.27)	0.54 (0.69)	0.17 (0.42)	0.33 (0.44)	0.17 (0.33)	0.33 (0.44)

6. Discussion

Lower accuracy requirements resulted on fewer errors of accuracy. This effect was found for all subjects and also for the different groups according to the users' profiles. It means that lowering the accuracy requirements facilitate drag-and-drop by reducing the number of supplementary gestures for accomplishing interaction. H1 is confirmed.

There are significant effects of user's profile on number of errors of accuracy for the following characteristics: age, sight, dexterity and use of computers.

The oldest groups made more errors during higher accuracy requirements. However, for both accuracy requirements as for lower accuracy levels, adults aged 80 years old or older made fewer REA than adults aged 75 to 79 or even adults aged 70 to 74.

Subjects with insufficient sight correction made more errors of accuracy than subjects with corrected sight and differences were significant for all games as well for lower and higher accuracy levels.

Concerning subjects with different dexterity abilities, the results of REA aren't significant different for lower or higher accuracy levels but subjects who reported upper-limb injuries or motor control difficulties made more errors than subjects with normal dexterity.

Concerning the experience of use of technologies, subjects who use computers made fewer errors than users who do not use computers, as indicated on the literature[3]. Use of computers showed significant effects on REA for all the situations of the study and for higher accuracy levels. But there is no significant difference for lower accuracy levels.

This result could explain the fact the oldest group of subjects execute more accurate drag-and-drop interaction. In fact, 67% of the subjects aged 80 years old or older use a computer while only 46% of subjects aged 70 to 79 years old use a computer.

These results demonstrate that lowering the accuracy requirements improves the accessibility of drag-and-drop interaction for subjects without experience of use of computers. Hence, H2 is confirmed for use of computers.

The absence of significant effects of use of touchscreen highlights the ease of use of tactile interaction. The evaluation of the interaction performances in the present study reveals that between novice and experienced older adults there is not a significant difference of number of errors of accuracy. In addition to that, it seems that drag-and-drop interaction and tactile puzzle games are intuitive and familiar for novice and experienced older adults.

Another interesting result is the effect of lower accuracy requirements on the variability betweensubjects. Apparently, low accuracy levels reduced the variability of number of errors of accuracy between subjects on global results but also for the different profiles.

7. Conclusion

The aim of the present study was to evaluate the effects of the accuracy requirements for positioning targets on touchscreen. 24 able-bodied older adults with different profiles (aged 65 to 86, corrected and not corrected eyesight, normal and low dexterity, different levels of education, different experience of use of computers and touchscreen) participated of the experience. They executed a series of tactile puzzle games on smartphone and tablet, with pen and fingers. Results show that lower accuracy requirements affect positively older users' performances. Lowering the accuracy requirements from 95% to 80% supported drag-and-drop interaction. Older adults made fewer errors of accuracy during lower levels and consequently fewer supplementary gestures for positioning the targets. Besides, this support technique also reduced the effects of user profiles improving the accessibility for people with no experience of use of computers.

Finally, we have demonstrated that lowering the accuracy requirements can be considered as a support technique for improving the accessibility of the tactile puzzle games.

The number of subjects can be considered a limitation of this study. Further studies need to be done with a more significant number of participants to better understand the effects of the user's profile, especially previous experience with technologies. Future work should compare our finding with a group of younger adults as a reference group.

As perspectives, this support technique should be applied to other interactive systems. Lower accuracy requirements should be helpful for graphical user interfaces where the number and the positions of targets don't allow the application of other support techniques such as expanding the size of the targets or the area of the cursor.

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