Re-establishing Interaction Through Design of Alternative Interfaces

Exploring new radio interfaces for elderly people with psychomotor disabilities

Suhas Govind Joshi
Department of Informatics
Faculty of Mathematics and Natural Sciences, University of Oslo
Oslo, Norway
joshi@ifi.uio.no

***Abstract*— This paper explores new opportunities for elderly people who are no longer able to use their radio due to changes in psychomotor capacities in hands and fingers. We explore whether three alternative self-developed radio interfaces can provide these elderly people with new interaction mechanisms in the radio that allow them to re-establish use. The three radios are used to conduct measurements of psychomotor performance among 52 elderly participants. Our main findings indicate that providing elderly people suffering from reduced psychomotor capacities with appropriate interfaces cannot only re-establish interaction but also yield performance scores comparable to the scores of elderly people without any apparent reduction in psychomotor capacities. We further present our additional findings from a quantitative analysis of performance and discuss discovered opportunities.**

Keywords — psychomotor abilities; elderly; radio; assistive technology.

I. INTRODUCTION

One of the most appreciated and well-used devices for elderly people in Norway are radios. The radio has been with them throughout most of their long life, and in a world of rapid technological development, the radio as a piece of technology has withstood the test of time. Phones have become mobile, smart, small, and multi-purpose devices, and televisions have become bigger, flatter and expanded with secondary functions. In a local care home in Oslo (with the average resident age of 84 years), which was part of our empirical context, we observed that 91% of the 90 elderly residents had a radio device in the home that they would use on an average day. However, as much as the residents desire to hold on to their radios, the process of aging introduces a variety of cognitive and motor challenges that complicate the use of even familiar and simple technologies. Our prior studies have demonstrated how something seemingly simple as a radio is not considered as simple or functional when aging symptoms appear [1].

The purpose of this paper is to discuss the need for alternative radio interfaces for older people who, because of disabilities or other bodily challenges, are unable to operate normal radios. We investigate whether new interfaces can re-enable interaction between radios and users who are no longer able to operate them. We present three different functioning radios that are specifically designed for older people and discuss the psychomotor properties of these interfaces regarding the interaction opportunities they offer. This study involved 52 participants from 2013 through 2015 in a systematic testing of our proposed interfaces. We use Fleishman's taxonomy of psychomotor abilities and skills [2] to identify and measure the participants' ability to operate the three different radios. To support our discussion, we present a statistical analysis of the gathered data. The results are used to demonstrate how various participants preferred different interfaces based on their psychomotor capacities, and how participants with motor challenges in certain cases were able to match the performance of elderly people without these challenges.

The paper is structured as follows. We introduce the motivation for focusing on the radio in Section 2, and we present related work on psychomotor and age-related studies within HCI in Section 3. In Section 4, the taxonomy used to describe and measure psychomotor abilities is defined. The research methods and three developed radios are described in Section 5 followed by results and analysis in Section 6. The paper ends with a discussion of why we believe new radio interfaces can help re-establishing psychomotor interaction with radios.

II. BACKGROUND

According to statistics from Statistics Norway (SSB), the older part of the population (aged 67-79) remains stable in the national average of radio listening in Norway [3]. The red line in Figure 1 shows an overview of the average percentage of the population who listens to the radio while the blue line shows the corresponding percentage for people aged 67-79.

The number of minutes in average spent listening to the radio is illustrated in Figure 2, and as we can read from the graph, there is only one recorded case in the past 23 years (1997) where the elderly fraction of the population on average would listen less to the radio compared to the general population. We can also read from Figures 1 and 2 that even in years where the number of elderly radio listeners was lower than the national average (i.e., 1994, 1995, 2001, 2009, and 2010), the number of minutes spent in front of the radio was higher for the elderly radio

 ISBN: 978-1-61208-470-1

listeners. The difference between the older generation and the rest of the population seems to have diverged over time, and the difference in a ten-year perspective is now greater than ever. The mean difference between the amount of time the elderly used for radio listening compared with the rest of the population in the period from 1991 to 2000 was 7.0 minutes while the corresponding difference in the period from 2005 to 2014 was over four times larger (33.1 minutes). This difference demonstrates an interesting phenomenon, namely that the radio as a piece of technology is not on its way to extinction. Quite the contrary, they are on the rise again regarding both share of the population that listens to the radio (Figure 1), and the number of minutes spent in front of the radio per day (Figure 2).

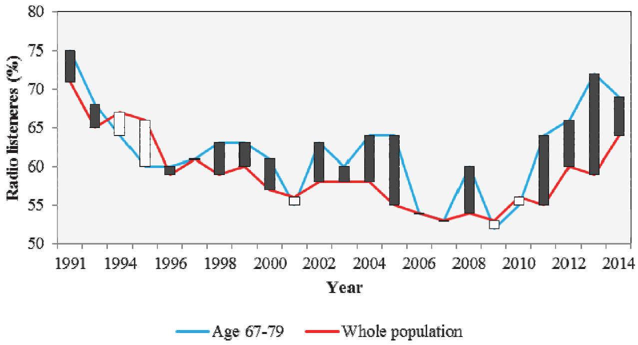

Figure 1. Percentage of population listening to the radio on an average day

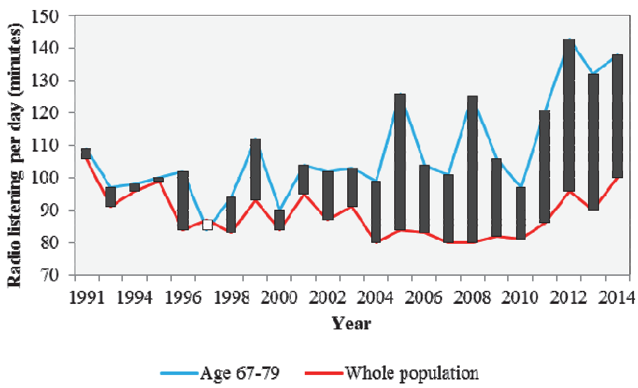

Figure 2. Number of minutes spent listening to the radio on an average day

In our prior research (e.g., [4] and [1]) we have discussed aspects of the role technology has in the lives of elderly people. We have touched upon related topics such as the social importance of being able to operate communicative technologies such as radios to stay in touch with the outside world [4]. We also explored deeper issues concerning the ability to operate such devices and the way such devices are presented, for instance, design that is oversimplified or stigmatizing [1]. These studies have concentrated on the experience of interacting with technology and would consequently be better suited to further discuss the social and contextual aspects of interaction with technologies, for instance, loneliness and boredom. However, in this paper, the focus remains on the psychomotor ability to interact with the radio, and more precisely re-establishing a lost relationship between old users and technology.

III. RELATED WORK

A long time has passed since researchers began systematically investigating the relationship between aging-related disabilities such as arthritis and the ability to interact with computers [5]. Morgan et al. [6] described significant differences in the execution of movement when comparing young adults with older adults, and more precisely the speed, sub-movements, and smoothness in movement. Similarly, Riviere & Thakor [7] use a comparative study between young, old, and motor-disabled subjects with regards to performance when operating tracking with a computer mouse. Their study claims that both aging and motor disability affect performance by increasing the inaccuracy and nonlinearity. Age has an apparent impact on our ability to interact and the extent to which we are able to adapt to new interaction mechanisms. This partly manifests itself through changes in psychomotor capacities. A recent study [8] claims the existence of age-related differences in the strategic repertoire, distribution, and execution within the sensorimotor domain. Regardless of the age of the intended user group, fine psychomotor abilities should be included in the determining of successful interactions [9].

One of the very few laws that attempt to descriptively explain the psychomotor role of human-computer interaction through mathematical formulas is Fitts' law. The original model was formulated over six decades ago and attempted described the linear relationship between movement time and index of difficulty. The model is still used today to quantify the difficulty of performing tasks and was in 2002 included in the ISO standard ISO 9241-9, which concerns non-keyboard input devices. However, since its conception, the model has undergone several modifications and refinements and does not pertain a universally accepted formulation today [10]. A shortcoming of Fitts' law is its ability to properly determine and evaluate differently observed result in the psychomotor performance when studying different task types, varying motor skills and differences in motor performance [11]. Others have argued that there are several factors affecting our endpoint performance that are not properly captured in the mathematical model [12].

In the context of aging, studies on how psychomotor abilities affect user performance with computer tasks within the field of HCI can also be traced back to at least the early 90s where researchers claimed and studied a relationship between the two [7]. Studies have been conducted within the field of HCI focusing on traditional interfaces, including WIMP and trackpads. For instance, psychomotor skills are an important part of the ability to operate a computer mouse, and several studies have investigated the relation between psychomotor abilities and use performance operating a mouse or trackpad [5][9][13]-[16]. Common for most of these studies is that they include several components that make up the list of psychomotor abilities described in Fleishman taxonomy, e.g., precision control, arm-hand steadiness, manual dexterity and wrist-finger speed [12].

IV. PSYCHOMOTOR ABILITIES

People undergo multiple reductions in both cognitive and motor skills as when entering later stages of life. In this study, we have chosen to focus on reduced psychomotor capacities in the hands and fingers, and how these changes affect the likeability to interact with radios. We have chosen not to describe this change as a limitation in the ability to interact since that would indicate an impossibility in an interaction between these individuals and the radio as technology. Instead, we believe that despite the undeniable changes in bodily capacities, our ability to interact with technology is not deprived, or necessarily not even reduced. We aim to demonstrate how adapting the technology to these changes in bodily capacities can prolong and re-establish interaction. Nevertheless, the focus of this study is older people with symptoms, illnesses, and diagnoses associated with reduced capabilities in the hands and fingers. This includes individual types of rheumatic disorder associated with hands and fingers, osteoarthritis, as well as more general motor system disabilities such as Parkinson's disease. Non-diagnosed elderly people showing symptoms affecting hands and fingers, such as trembling, involuntary movements, spasms were also included, as fine motor skills tend to decline with age [17]. We expanded our experimental group with elderly people claiming inability to operate radios, despite not being able to provide a medical record of a specific disability, as challenges associated with aging like inadequate blood flow and circulation to the muscles, injuries, stress, fatigue may also produce spasm in muscles that would reduce the psychomotor capacities. Several residents in our empirical context also reported similar symptoms of cramps from medical side effects, in particular from medication related to Parkinson's disease and Osteoporosis. Other types of developmental or genetic disorders that may have an impact on psychomotor capabilities, but that are not particularly prominent symptoms among the elderly people, were not included in this study (e.g., Down's syndrome, cerebral palsy and dystonia).

A. *Fleishman's taxonomy*

Based on cognitive, sensory, physical, and psychomotor factors, Fleishman derived 52 skills and abilities describing human performance. Although this model was initially developed for a job-related environment, the taxonomy of Fleishman describes abilities and skills that can be associated with performance in everyday tasks [18]. The taxonomy separates abilities from skills; abilities are defined as characteristics and traits shaped throughout the first phase of our lives while skills describe the degree to which we can effectively carry out an action directly related to a given task. Common for the two is that both skills and abilities related to psychomotor capacities involve complex movement patterns and require practice and maintenance in order to remain intact [19].

As the aging process does not follow a schematic or linear development, it is difficult to consider any abilities or skills as less relevant than others. For instance, the cognitive factor constitutes the biggest share of skills and abilities and is obviously relevant also in the discussion of aging-related reduction of interaction capacities. It is further apparent that some of the motoric challenges stem from changes in the cognitive capacities, e.g., ideomotor apraxia where changes in semantic memory capacity reduce the ability to plan or complete motor actions. Studying this category involves abilities and skills that fuse cognitive, perceptual and physical abilities [20].

Studies that focus on elderly people with motor challenges in their hands tend to carry an increased attention towards the abilities and skills that fall under the taxonomic category of physical factors. This is because the muscular restrictions and reduced bodily capabilities in the hands mainly tend to affect the abilities and skills covered by this category. Examples of abilities and skills included in this category are stamina, physical strength and flexibility, balance, and coordination. In previous studies of digital devices in the context of elderly people, we have been concerned with both stamina and physical strength (e.g., in [1]), but in this paper, we mainly focus on psychomotor factors. This is because most of the actions associated with the operation of a radio and other similar digital devices require movement and a configuration of hands and body that relies on the ability to combine physical movement with cognitive functions. Thus, psychomotor factors constitute our main interest, as this organically includes physical skills such as coordination, dexterity, reaction and manipulation. Unlike physical factors, psychomotor factors are also subjected to the influence of reduction in skills and abilities associated with secondary categories; psychomotor capacities often depend on a supportive capacity in addition to the physical. A reduction in other seemingly unrelated features (e.g., visual impairment) may, as Jacko & Vitense [20] point out, have an impact on psychomotor skills.

B. *Scope*

Our study is limited to psychomotor challenges of hands and fingers. Due to inadequate access to fully medically-assessed participants, as well as claimed expertise, we do not address the impact of the decline in cognitive abilities and skills in this paper (e.g., dementia, depression, and forgetfulness). Our scope does not allow us to identify the best interfaces for a given disease but instead let us study the relationship and possible correlation between motor challenges and performance when interacting with radio interfaces. Nor do we want to identify all skills and abilities that are included in the performance of work-related tasks; we aim to identify the specific abilities and skills that are involved in the operation of radios, and affected by reduced capacity in the hands and fingers. Abilities and skills in the taxonomy of Fleishmann are described as independent of each other [12], and it should consequently be possible only to study a selection of these. A similar approach has been conducted in prior research, more specifically in the research of [12, 14, 15, 16]. Table 1 gives an overview of the psychomotor abilities included in our study. A description is provided for each ability based on the original taxonomy of Fleishman [2] in the right column of the table.

TABLE I. OVERVIEW OF PSYCHOMOTOR ABILITIES

Psychomotor ability	**Description**
Precision control	Ability to move control and the degree to which they can be moved quickly and repeatedly to exact positions.
Arm-hand steadiness	Ability to keep the hand and arm steady, both when suspended in air and while moving. Independent of strength and speed.
Manual dexterity	Ability to make quick and skillful coordinated movements with arms and one or both hands, as well as the ability to assemble, grab and move objects.
Finger dexterity	Ability to make quick, skillful, and coordinated movements with fingers of one or both hands.
Wrist-finger speed	Ability to repeat fast movements with wrist and fingers.
Multi-limb coordination	Ability to use two or more limbs simultaneously to coordinate movements when the body is not in motion.

While all the abilities and skills described in the psychomotor category of the taxonomy are relevant in a broader scope, we have excluded certain abilities and skills from our test. These are abilities that are not relevant for our purposes, and the decision is taken by both the physical challenges we are focusing on, and the digital components and interfaces included in the study. Not all abilities are relevant for the operation of our radios; hence, measuring these abilities would be difficult with the radios. More precisely, rate control, reaction time, speed of limb movement, and response orientation have been excluded. The reason is that these four abilities are not directly determining the capacity to interact with our three radios, but instead, describe the degree to which we can interact with them, as well as the performance during use. Rate control is not appropriate in situations where speed and direction of an object are perfectly predictable [20] while the other three (reaction time, speed of limb movement, and orientation response) mainly concern efficiency of performance, rather than the distinctive ability to perform them. Also, both reaction time and response orientation are intended to capture our reaction to a given signal and our ability to quickly initiate the response routine, something which would be unnatural in a context where our participants are testing our radios. Thus, these four abilities have not been included in our tests.

V. RESEARCH METHOD

A. Radio #1

The first radio is the leftmost radio in Figure 3, and it was developed in 2013. The focus of the radio is to provide an interface that provides users with similar experiences and interaction mechanisms as they are used to from their traditional radios. The feedback one gets from operating radio is reminiscent of interaction found in traditional radios with a distinct response to actions. The focus has also been on finding the materials that provide the best grip and resistance during the interaction. We have explored the properties of various materials (wood, steel, plastic) to find the best functioning design for the knobs. The main interaction takes place by turning on a coarse switch that clearly snaps in place when selecting the channel. A second switch is used to adjust the volume.

Figure 3. The three radios included in the study

B. *Radio #2*

The second radio is the middle radio from Figure 3, and was developed in 2014. This radio depends on physical interaction and does not use traditional switches or buttons. As with the other two radios, this radio is also screenless. The user operates the radio with the use of wooden cubes with built-in Near Field Communication (NFC) chips. The NFC chips are preconfigured with a given radio channel, and by placing these physical cubes on top of the radio, one interacts with the interface. By placing a piece with a given channel on top of the radio starts playing. Removing the cube ends the playback. The focus has been on designing a radio that does not require fine motor skills in fingers. During the design process, material, weight, size and shape were explored in consultation with users to find the best objects for physical operation of the radio.

C. *Radio #3*

The third radio is the rightmost radio in Figure 3, and was developed in 2015. The purpose of this radio was to allow users with tremors, involuntary twitching, and reduced fine motor skills to operate it. The radio is made of oak and has an aluminum cylinder with a wooden knob that automatically snaps to predefined positions using magnets. One operates the radio by positioning the wooden knob at a predefined position. A secondary exploratory feature is that the wooden knob swivels around the cylinder. The design of the radio offers deliberate constraints that prevent users from making mistakes during the interaction. The wooden knob is locked to the pole and the magnet in the cylinder both guides and limits the positioning. This allows involuntary actions to have less impact on the accuracy.

D. *Empirical context and participants*

This study was conducted at three local care facilities in Oslo. Each care facility consists of a set of apartments, with the largest holding 90 apartments. The care facilities consist of senior residents residing in independent apartments, but with shared access to a range of facilities, e.g., cafeteria, lounge, fitness center, and 24-hour staffed reception. The limited access to participants with motor challenges in hands and fingers led to three years of data gathering in order to yield an appropriate set of data. The requirement for participation was that the participant suffered from reduced ability or no ability to operate a store-bought radio and thus needed a more customized interface. The three store-bought radios used for participant selection were Pinell Supersound DAB, Pop DAB Radio and Argon DAB Radio, three highly popular brands in Norway. The data for this study was collected in the period 2013-2015. The three radios used in the tests were also built during the same period. 39 participants (M = 82.1 years, SD = 6.31) participated in six tests. For each test, we recruited an independent control group consisting of 13 elderly people with no apparent motor disabilities (M = 80.4 years, SD = 5.29) who were asked to perform the same tasks as the experimental group.

The testing involved 52 participants in total. Most people had medical documentation to assess their motor disabilities. The documentation was provided to us by themselves or by the local care home administration with their consent. A few participants unable to operate store-bought radios and in the lack of proper medical documentation of disability were also invited to participate in the experimental group as they showed symptoms similar to those with proper diagnoses. Table 2 gives an overview of the participants and the documented or self-assessed disability or illness.

TABLE II. OVERVIEW OF PARTICIPANT GROUPS

Disability or illness	**N**
Cramps	8
Muscle stiffness	3
Osteoarthritis	8
Parkinson’s disease	4
Rheumatoid arthritis	3
Tremor	13
Control group	13
Total	**52**

E. *Test procedure*

The participants in both groups were asked to interact with the three radios through a series of repeated tasks to measure their psychomotor performance. Three different tables and eight chairs were used to provide all participants with a setup that supported their preferred bodily configuration. Some participants were also sitting in their wheelchairs during the test, specifically three participants from the experimental group and one participant from the control group. For each of the radios, the participants were given a set of tasks that mimicked the context applicable parts of assignments given in standardized tests of psychomotor abilities, e.g., rotary pursuit test, steadiness tester, Minnesota manual dexterity test, Purdue pegboard, tapping board (as seen in [12], as well as O’Connor finger dexterity test, box and block test, Jebsen hand function test, and Moberg pick-up test. As we used our own set of tasks, the results are not meant to demonstrate the external validity and be directly comparable to other test results, but instead provide a set of tasks applicable to the three radios, thereby providing us with a measurement comparable within the study. To eliminate learning effects and bias due to unfamiliarity with novel interaction mechanisms, each participant was given a demonstration of the intended interaction of each radio, and each participant conducted ten trials for each radio (similar to [5]). The task order was randomized for each participant. We relied on randomized repeated measures to minimize bias due to interpersonal variations between tests. The task set consisted of 12 tasks: gripping, turning, positioning, re-positioning, and resetting the main and secondary interaction element, as well as lifting and moving the radio. Time (seconds), error (count) and precision (position and distance) were observed and measured for each task, and the performance was graded on a normalized scale from 1-10 to make the performance metrics comparable. The computationally-generated normalized score used the four metrics above (seconds, count, position, and distance) to calculate the final score. Thus, the performance scores are not intended to be comparable beyond the scope of our research. In Figure 4, we see two participants from the experimental group testing the positioning and re-positioning of the main interaction element for Radio #2.

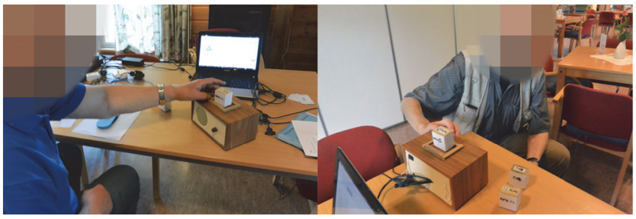

Figure 4. Two residents participating in psychomotor measurements

VI. RESULTS AND ANALYSIS

The means and standard deviations for the psychomotor performance on a normalized scale from 1-10 across both groups are shown in Table 3. As expected, the control group had a better performance relatively compared to the experimental group for all three radios. The variation was larger for the control group, and we can read from the table that both groups demonstrated a similar within-group performance for each of the three radios. The average performance score was 7.43 (SD = 0.32) for the control group while it was 4.60 (SD = 0.22) for the experimental group. In Figure 5, we present the estimated marginal means for the control group vs. the regular group for all three radios.

TABLE III. PSYCHOMOTOR PERFORMANCE SCORE

Radio #	Group	Mean	Std. Deviation	Lower Bound	Upper Bound	N
1	Control	7.385	.7372	6.730	8.039	13
	Experimental	4.517	1.2824	6.471	7.658	39
2	Control	7.064	.5755	7.156	8.536	13
	Experimental	4.389	1.1787	4.139	4.895	39
3	Control	7.846	.4328	4.046	4.732	13
	Experimental	4.897	1.4000	4.499	5.296	39

A 2 (group: selection or control) x 3 (radio: #1, #2 or #3) between-subjects analysis of variance (ANOVA) was conducted to study the psychomotor performance between the three radios as a function of the performance. We registered significant main effects of group, $F(1,150) = 173.6$, $p < .005$, n = .536, and radio, $F(2,150) = 3.1$, $p = .048$, n = .040. The main effects were not qualified by an interaction between group and radio, $F(2,150) = 0.142$, $p = 0.867$, $\eta p^2 = .002$. The participants in the selection group (M = 4.601, SD = .107) had significantly lower performance than the participants in the control group (M = 7.432, SD = .186). The analysis also revealed a slightly lower performance difference between the three radios: (M = 5.951, SD = .186), (M = 5.726, SD = .186), and (M = 6.372, SD = .186). Levene's test for equality of variances was found to be violated for the present analysis (p = .001), and Bonferroni post-hoc analysis for the radios showed that Radio #2 had significantly lower performance than Radio #3 at the .05 level, while differences between Radios #1 and #2 and Radios #1 and #3 were not significant.

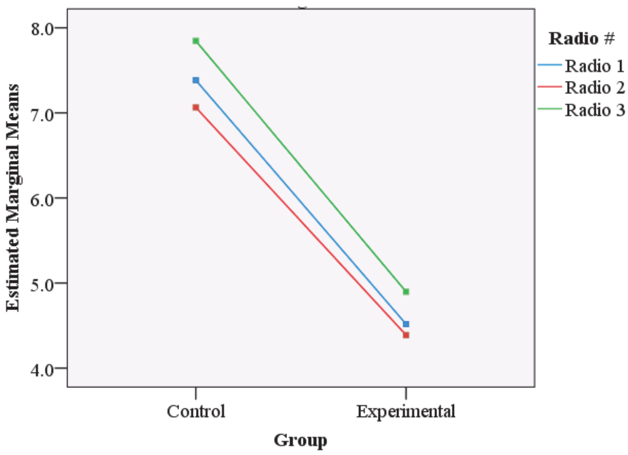

Figure 5. Estimated marginal means of performance for both groups

The results from Figure 5 only demonstrated how the estimated marginal means of the overall performance for all participants in the treatment group compared to the control group. For a post hoc evaluation of the performance within the experimental group, we performed a separate repeated measure analyzes for each level within the grouping factor to study the relationship between performance and psychomotor disability.

We analyzed the data with mixed-design ANOVA using a within-subjects factor of disability (cramp, muscle, osteoarthritis, Parkinson's disease, Rheumatoid Arthritis, Tremor) and a between-subject factor of radio (Radio #1, Radio #2, and Radio #3). Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 2.681$, $p = .026$). Degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = 1.000$) as Greenhouse-Geisser estimates reported an epsilon value above 0.75 ($\varepsilon = .926$) [21]. There were non-significant main effects of disability, $F(2, 66) = 5.566$, $p = .006$ and radio, $F = (1, 33) = 8.129$, $p = .007$. However, the main effects were qualified by a significant interaction between disability and radio, $F(10, 66) = 17.011$, $p < .001$. In Figure 6, we demonstrate how the interaction between disability and radio yielded a significant variation in the estimated marginal means of performance.

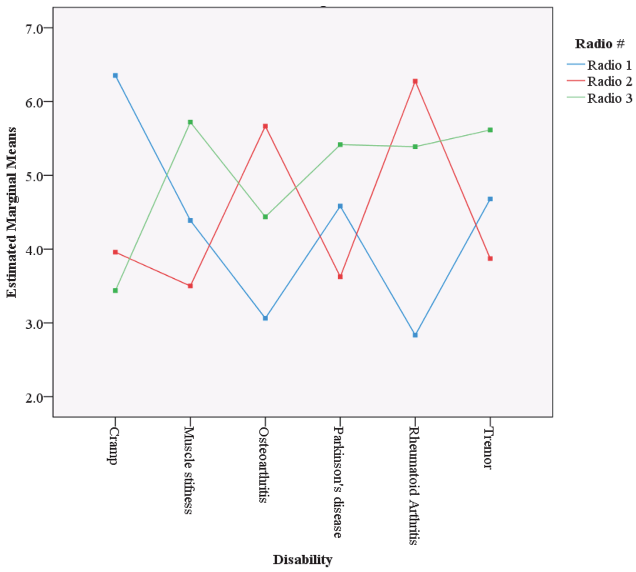

Figure 6. Performance for each disability group across all three radios

Again, the statistical results of this study do not attempt to provide a medical explanation for the performance but instead demonstrates a significant correlation in order to exemplify the need for various interfaces when addressing elderly people with psychomotor disabilities. The study only claims the presence of a significant difference in performance but does not provide any solutions.

VII. DISCUSSION

A. *Psychomotor disabilities as a shift rather than a loss*

The analysis presented in the previous section demonstrates some important findings. First and foremost, we see that grouping all elderly people in one common category cannot be considered scientifically justifiable when their needs, capacities, and performances are so different. To group the elderly in one common category is both stigmatizing and improper design practice as it neglects individual needs. Also, we have presented empirical data suggesting that even the specific group of older people suffering from motor deficit in the hands and fingers would highly benefit from designs that paid individual attention to their needs.

At first glance, it might look like Figure 5 illustrates a steady and consistent difference between the control group and the experimental group. However, this was not the case. Irregularities in performance resulted in statistically counteracting mean values, and glancing at Figure 5 one may wrongfully conclude that the older participants yielded a seemingly equal performance score for each radio regardless of their motor capacities. However, as presented in the secondary analysis of the relationship between disease and performance (illustrated in Figure 6), we see performance scores with high fluctuation within each group. We can confirm this by looking at the statistical analysis which indicated a significant interaction between disability and radio ($p < .001$).

One way of understanding this phenomenon is to look at average performance score for each group. The participants who suffered from trembling serve as a good illustration. This group, which accounted for a third of the participants in the experimental group, had the lowest performance score on Radio #2 ($M = 4.19$, $SD = 0.40$), an intermediate performance score on Radio #1 ($M = 05.07$, $SD = 1.57$), and the highest on Radio #3 ($M = 6.08$, $SD = 0.98$).These results can be explained by the different types and various symptoms of tremor. Participants reported issues with intention tremor that could affect their aim, specific tremor which influenced goal-oriented action), as well as general stressing tremor. As Radio #2 required participants to raise a cube in midair and place it within a designated area, it was difficult for several participants to operate this radio. With more degrees of freedom compared with the other two radios, there was more room for both intentional and deliberate errors. This group performed best on Radio # 3 as involuntary movements would not give adverse effect or hinder progress in solving the task.

A similar pattern can be seen in the group of participants who suffered from Rheumatoid Arthritis. They reported challenges with swelling, decreased sensitivity and reduced mobility, which resulted in problems with the interface of Radio# 1 ($M = 2.83$, $SD = 0.99$). The reduction in sensitivity in particular would mean that they struggled more with sensing moving, clicking, and snapping feedback from the radio. However, they delivered a good average performance score for Radio # 2 ($M = 6.28$, $SD = 1.74$), suggesting that they still had the capacity for interaction.

Thus, loss or reduction in motor capacities does not an automatically reduce or deprive our interaction opportunities; it mainly shifts them. All three of our radios were developed to allow people with motor impairments in their hands and fingers to still use these limbs for interaction. And our results suggest that they are highly capable of doing so if presented the right interface. In their studies of differences in pointing movements between older and younger users, [16] argues that older people maintain the use of residual sensory information (vision and proprioception) and can achieve similar precision levels as younger users. However, the radios in our study do not need to be operated by hands and fingers. There are also opportunities explore new bodily uses and configurations. In certain context, radios are naturally operated through different interaction mechanisms, for instance in cars. Prior studies have also demonstrated interaction opportunities for people with motor disabilities by the use of other bodily capacities. For instance, [22] use head gesture recognition for wheelchair control for elderly people suffering from Parkinson's disease and other restrictions in limb movement. The authors of [23] study wrist rotation as input mechanisms for mobile devices, and suggest that both hands-free and eyes-free interaction techniques would be feasible with further research. The research of [24] uses a voice-driven drawing application to include users with motor impairments.

We should never exclude any people as potential users just because their capacities prevent them from using a given interface. Incompetence or inability in use should not be tied with technologies, but instead, be a use dimension related to the specific interaction mechanisms that the technology provide. Radio might be considered one piece of technology, but there are limitless opportunities when it comes to the way it is presented to the user. The results in this paper have demonstrated that people can re-establish meaningful relationships with technology by shifting the way of presentation.

B. *Extending and re-establishing purposeful interactions*

It is important to note that none of the three radios was perceived as uniformly better than the rest. Each radio would yield good scores with one or more groups, but there was always another group that would struggle with the same interface. This supports our claim that radios designed for a specific group of people, and with features that may even fully compensate for the motor deficit, will still not necessarily work for everyone. Hence, the results of this study demonstrate not only the need but also the possibility, to make individual adjustments in the design of interfaces. Even though we developed three radios, they all utilized nearly identical hardware, and the basic electronic components are the same in all three radios. The back of the three radios and how their hardware is enclosed in similar casement taking up roughly the same size is demonstrated in Figure 7. They were developed in three independent processes focusing on various psychomotor challenges, yet we see that only the packaging, i.e., the "outer shell" enclosing technology, is changed. By designing three different interfaces, we have shown that it is possible to re-enable an entire group of elderly people who would otherwise have to abandon interaction with radios. And we achieved this while letting them continue to use their hands and fingers, something which is not a requirement for successful interaction. If we expand the design area to include all other bodily capacities, the potential to re-establish purposeful interaction would be even greater, and the chance is simultaneously greater for technology to remain meaningful longer, even when living through a decline in psychomotor capacities. To offer users a variety of interfaces on top of the technology also provides users the ability to customize the interaction to their capacity levels, even if they were to discover at some point that some of their motor skills develop in a positive sense. Adapting to skill levels is encouraged by [19]. It would also open up more room to address changes in movements, actions and bodily configurations as psychomotor skills among user group changed. The authors of [6] suggest that there is a natural discontinuation in slow movements among older people. This is also supported by [5] who suggest that older participants depend on interfaces that allow for more sub-movements in interaction. In general, it is considered reasonable to spend more time on interface adaptations since the majority of prior research only studied two-factor analysis of the interaction and psychomotor capacity in a context where other conditions such as frequency of use and expertise could have had an impact on the interaction [9].

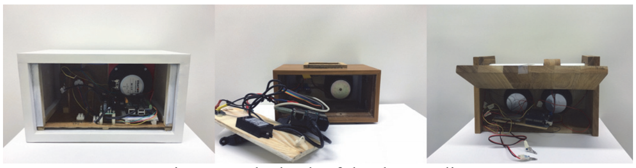

Figure 7. The back of the three radios

In our empirical context, this idea of introducing multiple interfaces is particularly important as Norway is facing an infrastructural change where all radios are switching from FM broadcasting to digital audio broadcasting (DAB). This will render all current FM radios unusable as of 2017. People with older radios are forced to buy new devices where the interaction may depend on users properly learning and understanding new interfaces, new terminologies, new frequencies and new mechanisms. However, prior research simultaneously suggests that elderly people are less willing to modify current strategies or adapt new strategies [5, 25]. This forced transition gives us a golden opportunity to introduce a variety of interaction mechanisms that can be incorporated into routines and habits while people are relatively able-bodied and only shows early symptoms. By doing so, the technology could potentially remain with them even if they were to enter a downward phase with reduction of capacities. If someone should not develop symptoms consistent with the expectations, having incorporated these new interaction mechanisms may still have a positive effect as it is often the underlying factors that are to be blamed for reduction of psychomotor skills, e.g., in the performance of tasks aiming [12].

Another important factor is the degree of stigmatization associated with use. Technology tailor-made for a certain group of people often succumbs to design choices so distinctive that other people can interpret the intended users their weaknesses just from the design itself. Our participants claimed that all three radios, but, in particular, Radio #3, had looks that did not suggest being specifically designed for the target audience. The design did not emit the stigmatizing radiance often found in technology tailored for the elderly [4]. To early expose users interfaces that can have a secondary function ago, will also allow older staple acquaintances interaction mechanisms not yet been vital for their use. Thus, there is less chance that they will experience the design and interface as stigmatizing about it sometime in the future should be such that it was the specific interaction mechanism that allowed interaction; interaction is associated with routines and habits rather than to impose solutions. Early exposure to interfaces that can have a secondary function later will also allow older users to make acquaintances with interaction mechanisms that have not yet become vital for their use. This would mean fewer chances of experiencing the design and interface as stigmatizing, even though it sometime in the future may become the very interaction mechanism allowing interaction; the interaction is associated with routines and habits rather than to imposed solutions.

This discussion of avoiding stigmatizing design further aligns with the idea of universal design. Design tailored for specific disabilities or illnesses does not exclude people without disabilities from using them. On the contrary, we found that the design of our three radios, and, in particular, Radio #3, appealed to participants and stakeholders that were not in the user group such as family members, employees at the care home, and even our self as designers. In future research, it would be interesting to investigate this aspect of the design further. While our results does not provide any significant evidence of one radio fully re-establishing interaction for all types of psychomotor disabilities, we did see examples of radios elevating the interaction performance to the level of the control group for multiple types of disabilities and illness (as demonstrated with Radio #1 and Radio #2 in Figure 6). It is therefore not unreasonable for further research on this topic to generate designs that can reach even more people and help users achieve even better performance scores. Nevertheless, the aesthetics of the three radios demonstrate the important underlying idea that design tailored for a specific user group can very well be fully usable and appealing to everyone. There is no reason that design for elderly people cannot be design for all.

VIII. Conclusion

In this paper, we have discussed the opportunities to re-establish interaction through the use of alternative interfaces. We have studied the case of elderly people suffering from a reduction in psychomotor capacities in hands and fingers to demonstrate how three different radio interfaces allowed them to return to the use of radios. Six rounds of tests were conducted with 52 participants in 2013-2015. We demonstrate how none of the three radios were universally acclaimed, and how extending and re-establishing purposeful actions require a more nuanced and adapted interface, even for a specific demographic as the one included in this study. Our main findings suggest that providing interfaces that acknowledge and compensate for psychomotor disabilities can re-enable interaction comparable to the level of fully-functional users.

To investigate our findings further, we aim to conduct a long-term testing with these proposed models that will yield qualitative data better suited for an interpretive analysis; the addition of subjective opinions and experiences from elderly users living alongside our proposed designs will help support the claims presented in this paper. The work presented in this paper encourages further research into opportunities for re-establishing interaction. Our particular case should also only be considered a starting point for similar research with a different or expanded scope. We have studied a limited set of challenges, i.e., psychomotor disabilities in hands and finger, but we would like to advocate further research on similar topics such as discussion of other types of psychomotor abilities or the role of cognitive capacities in re-establishing interaction.

References

[1] S. G. Joshi, “Designing for Experienced Simplicity. Why Analytic and Imagined Simplicity Fail in Design of Assistive Technology.” The International Journal on Advances in Intelligent Systems, vol. 8, no. 3&4, 2015, pp. 324-338.

[2] E. A. Fleishman and M. E. Reilly, “Handbook of human abilities: Definitions, measurements, and job task requirements.” Consulting Psychologists Press, 1992.

[3] S. Norway, "Norwegian Media Barometer, 2014," SSB.

[4] S. G. Joshi, "Emerging ethical considerations from the perspectives of the elderly," in Ninth International Conference on Cultural Attitudes in computer-Human Interactions, M. Strano, H. Hrachovec, and S. Fragos, 2014, pp. 1-15.

[5] M. W. Smith, J. Sharit, and S. J. Czaja, “Aging, motor control, and the performance of computer mouse tasks.” Human Factors: The Journal of the Human Factors and Ergonomics Society, vol. 41, no. 3, 1999, pp. 389-396.

[6] M. Morgan, J. G. Phillips, J. L. Bradshaw, J. B. Mattingley, R. Iansek, and J. A. Bradshaw, “Age-related motor slowness: simply strategic?.” Journal of gerontology, vol 49, no. 3, 1994, pp. M133-M139.

[7] C. N. Riviere and N. V. Thakor, “Effects of age and disability on tracking tasks with a computer mouse: Accuracy and linearity.” Journal of Rehabilitation Research and Development, vol. 33, 1996, pp. 6-15.

[8] C. Poletti, R. Sleimen-Malkoun, J.-J. Temprado, and P. Lemaire, “Older and younger adults’ strategies in sensorimotor tasks: Insights from Fitts’ pointing task.” Journal of Experimental Psychology: Human Perception and Performance, vol. 41, no. 2, 1994, p. 542.

[9] C. Sutter and M. Ziefle. “Psychomotor user characteristics as predictors for a successful usage of small input devices.” in Proceedings of the HCI International 2005, pp. 1-11.

[10] R. W. Soukoreff and I. S. Mackenzie, “Towards a standard for pointing device evaluation, perspectives on 27 years of

Fitts' law research in HCI." International journal of human-computer studies, vol. 61, no. 6, 2004, pp. 751-789.

[11] C. Sutter and M. Ziefle. "Psychomotor performance of input device users and optimized cursor control." in Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications. 2006, pp. 742-746.

[12] Y. Cheong, R. L. Shehab, and C. Ling, "Effects of age and psychomotor ability on kinematics of mouse-mediated aiming movement." Ergonomics, vol. 56, no. 6, 2013, pp. 1006-1020.

[13] Y.-K. Cheong, "Performance and movement kinematics of mouse pointing task: Perspectives from age, psychomotor ability, and visual ability," University of Oklahoma, 2007.

[14] N. Đorđević, D. Rančić, and A. Dimitrijević. "Evaluation of User Cognitive Abilities for HCI." in Proceedings of the 11th WSEAS International Conference on COMPUTERS, Agios Nikolaos, Crete Island, Greece. Citeseer. 2007, pp. 468-473.

[15] J. Knight and G. Salvendy, "Psychomotor work capabilities." Handbook of industrial engineering, 2nd edn. Wiley-Interscience, New York, 1992, pp. 978-989.

[16] L. Zhang, J. Yang, Y. Inai, Q. Huang, and J. Wu, "Effects of aging on pointing movements under restricted visual feedback conditions." Human movement science, vol. 40, 2015, pp. 1-13.

[17] B. Makofske, "Manual Dexterity," in Encyclopedia of Clinical Neuropsychology. Springer, 2011, pp. 1522-1523.

[18] A. Furnham, S. Von Stumm, A. Makendrayogam, and T. Chamorro-Premuzic, "A Taxonomy of Self-Estimated Human Performance: The General Factor." Journal of Individual Differences, vol. 30, no. 4, 2009, pp. 188-193.

[19] M. H. Fogtmann. "Kinesthetic empathy interaction– exploring the possibilities of psychomotor abilities in interaction design." in Second International Workshop on Physicality, 2007, p. 37.

[20] J. A. Jacko and H. S. Vitense, "A review and reappraisal of information technologies within a conceptual framework for individuals with disabilities." Universal Access in the Information Society, vol. 1, no. 1, 2001, pp. 56-76.

[21] A. Field and G. Hole, "How to design and report experiments." Sage, 2002.

[22] J. Gray, P. Jia, H. H. Hu, T. Lu, and K. Yuan, "Head gesture recognition for hands-free control of an intelligent wheelchair." Industrial Robot: An International Journal, vol. 34, no. 1, 2007, pp. 60-68.

[23] A. Crossan, J. Williamson, S. Brewster, and R. Murray-Smith. "Wrist rotation for interaction in mobile contexts." in Proceedings of the 10th international conference on Human computer interaction with mobile devices and services. ACM. 2008, pp. 435-438.

[24] S. Harada, J. O. Wobbrock, and J. A. Landay. "Voicedraw: a hands-free voice-driven drawing application for people with motor impairments." in Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility. ACM. 2007, pp. 27-34.

[25] N. Walker, D. A. Philbin, and A. D. Fisk, "Age-related differences in movement control: Adjusting submovement structure to optimize performance." The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, vol. 52, no. 1, 1997, pp. 40-53.