Introduction

Touchless human-computer interaction technologies (TTs), such as, gesture cameras and voice control devices, have been available within the domestic setting for many years (i.e. Amazon Alexa, Apple Siri, Microsoft Cortana & XBOX Kinect). Over recent years, there have been growing reports of the use of TTs within medicine[1] including the use of voice and gesture control technology for surgery[2] and anaesthesia[3]. In the true sense, voice activated technologies have been used in radiology for many years in the form of electronic dictation software. If we exclude dictation then the current utilisation of TTs have largely been reserved for ultrasound[4] and interventional radiology[5]. The study by Bravo, Coffin and Murphey[4] sought to determine the efficacy of voice activated technology to reduce the muscle activity required by the non-scanning arm which was required to manipulate the keyboard and controls of the ultrasound machine. The authors of this study argued that by showing a reduction (91%) in the number of keystrokes this demonstrated a reduction in muscular effort. Reduction of muscular effort and a decrease in sustained postures can prolong muscular endurance during work-based tasks. The study by Hettig et al.[5], based in interventional radiology, evaluated two gesture input modalities used to control an image selection task. The input modalities were evaluated in terms of the task completion time, perceived task difficult and subjective workload. Overall, the authors concluded that gesture control failed to exceed the clinical input approach but future developments, which consider task complexity, should be further evaluated. Currently, to the authors' knowledge, there are no peer-reviewed publications reporting the use of TTs within general X-ray examinations.

One of the fundamental requirements for the successful acquisition of X-ray images is the correct and efficient use of imaging equipment. With modern systems, many acquisition parameters are pre-selected prior to the patient entering the X-ray room. Such pre-selections are made possible due to interactions between the Digital Imaging and Communications in Medicine (DICOM) Worklist and the Anatomically Programmed Radiography (APR) settings stored within the modality[6, 7]. In many cases, these pre-determined parameters will remain unchanged and a diagnostically acceptable image will be generated with relative ease. However, for some patients, modifications to the environment will be required. Such changes would only become apparent upon meeting the patient and likely reflect the body habitus of the patient, their clinical condition, level of co-operation and mobility. Timely modifications to the imaging protocol are necessary to achieve a successful and efficient examination. To achieve this, repeated journeys between the acquisition console, X-ray tube and patient may be required. Such movements can be time consuming and could adversely affect examination success, for example during paediatric examinations where timing can be critical[8]. Opportunities to minimise such movements exists from utilising TTs within diagnostic radiography, however such options do not routinely exist within currently commercially available X-ray equipment. This study aims to evaluate the potential utilisation for TTs within digital X-ray examinations.

Methods

Research Ethics

Ethics approval was granted by the University of Salford Health Sciences Research Ethics Committee (HSR1920-054).

Survey Design

An online survey was delivered via the European Federation of Radiographer Societies (EFRS) Research Hub. The survey contained ten themes and was designed to investigate the potential for TTs (voice and gesture control) within X-ray rooms. The survey was intended to be completed in under 20 minutes. No incentive was offered for survey participation. The Survey Monkey online platform (www.surveymonkey.com) was employed as the survey tool and anonymous responses were collated in MS Excel (Microsoft Inc, Redmond, WA) for analysis.

Participants

Questionnaires were distributed via electronic links through the European Federation of Radiographer Societies (EFRS) 2020 Research Hub. The Research Hub was an online platform (www.efrs.eu) and promoted a series of online questions to its member organisations and wider, as part of the ECR2020 Summer Online congress. Eligible participants could be students or qualified radiographers, located within any country and did not need to have registered for the ECR2020 congress.

Questionnaire Design

The questionnaire comprised of open and closed questions and consisted of sections designed to ascertain data on: participant demographics (seven questions), current use of TTs at home and in the workplace (two questions), potential uptake of TTs in radiography (one question), tasks potentially suitable for voice and gesture control (four questions), potential areas for TTs in practice (one question), limitations of TTs (one question) and whether TTs could be used in clinical practice (one question). The questionnaire was designed using information obtained from the literature and input from the study authors. The questionnaire was developed in English and subject to piloting and validation. Piloting was achieved by sending the questionnaire to several research active radiographers and asking them for feedback on the questions and the time required to complete the questionnaire. Feedback from the pilot study required only minor modifications to several of the questions. Face validity of the questionnaire was achieved by supplying the aims of the study and the questionnaire to two of the study authors and asking whether the questionnaire appeared to meet the study aims.

Data Analysis

Quantitative data from closed questions were analysed using descriptive and inferential statistics. Frequencies were reported together with their respective percentages. Data were examined for normality visually and using the Shapiro-Wilk test. Using the Shapiro-Wilk test, p values <0.05 were considered indicative of non-normally distributed data. Correlation analyses were undertaking comparing engagement with home based TTs and enthusiasm for TTs within the clinical environment. Where data were normally distributed the Pearson correlation coefficient was used, for non-parametric data the Spearman correlation coefficient was used. P values of <0.05 were considered statistically significant.

Results

Participant demographics

155 respondents completed the questionnaire, 147 indicated that they were from 22 different countries (**Table 1**). The demographics, qualifications and experience of the respondents are summarised in **Table 2**. The majority of respondents had a Bachelor's degree (n=54, 35.1%) and there was a good distribution of responses with respect to experience and

work area. At the time of the survey, a large proportion of respondents were currently working in general X-ray (n=107, 69.5%).

Prior experience of touchless technologies

Approximately half (n=80, 55.6%) of respondents owned and used voice activated TTs in the home (**Figure 1**). Gesture based TTs were infrequently owned and used by 12 (8.6%) respondents. 77 (54.2%) of respondents were considering purchasing home automation TT devices.

Within the workplace, 25 (16.1%) of respondents indicated that they had access to TTs. 117 (75.5%) respondents stated that they did not have access and 13 (8.4%) reported that they 'did not know' if they were available. When asked how likely participants thought that TTs would become part of radiographic practice over the next decade the mean ± SD was 6.6±2.3 (0=very unlikely and 10=very likely).

Potential role for TTs within general radiographic practice

Respondents were invited to indicate their opinions for the potential role of TTs within radiographic practice. Results were stratified according to the stage in the radiographic examination and by type of TT (voice or gesture) (**Tables 3–6**). In terms of tasks performed prior to positioning the patient / moving the X-ray equipment (**Table 3**), participants favoured voice commands over gestures. Inviting the next patient into the X-ray room and loading up the next patient from the Worklist were considered by over 70% of participants as 'highly likely' or 'likely' to be assisted by voice commands. In terms of gesture activated tasks, loading up the next patient from the Worklist was considered either 'highly likely' or 'likely' by 60% of respondents.

In terms of tasks performed during the X-ray examination – positioning the patient / equipment (**Table 4**), participants again favoured voice commands over gestures. Moving the X-ray tube into a protocol defined position, via voice control, was considered to be either 'highly likely' or 'likely' by 88% of participants. In terms of gesture-based commands, moving the table / wall stand into a protocol defined position was considered to be 'highly likely' or 'likely' by 62% of participants. Correlation analysis revealed no significant trends between engagement with domestic TTs and enthusiasm for TTs within the clinical environment ($R=-0.06$, $p>0.05$).

In terms of tasks performed following X-ray exposure / image acquisition (**Table 5**) participants again favoured voice commands over gestures. In terms of voice control, initiating changes to room lighting was considered either 'highly likely' or 'likely' by over 90% of respondents. For gesture control, the results were similar but also gesture control was considered favourably for managing room music and distraction interventions.

In terms of tasks performed at any time during the X-ray examination (**Table 6**), participants again favoured voice commands over gesture based TTs. In terms of voice control, initiating changes to room lighting was considered either 'highly likely' or 'likely' by over 90% of respondents. For gesture control, the results were similar.

When considering which elements of practice may benefit from voice or gesture based TTs, helping improve examination efficiency (speed) was considered to have the greatest potential (**Table 7**). By contrast, data safety was the area of practice seen as least likely to benefit from voice control. In terms of gestures, exam efficiency was the area seen of potential greatest benefit, whereas patient identification was perceived as the least likely beneficial area.

Discussion

The use of TTs in daily life is increasing, with Amazon reportedly hiring an average of 14.2 more employees daily to work on their Alexa and Echo systems[9]. Within the United States, 14 million people owned a smart speaker in 2018 and this has risen to 51 million in 2020[10]. Voice activated TTs enable users to navigate, listen to music, send messages, control home devices, order goods and services, among others. Mewes et al.,[11], reported an increasing use of TTs within medicine to deal with the control of medical image viewers but the current work is the first study of the opinion and experiences of radiographers using TTs. The personal use of voice activated TTs (43%) in our study was greater than in the general population[10] and may represent the nature of the target audience and also the narrower age range. This trend could also be the result of respondent bias in that those with an interest in TTs were more likely to complete the survey. Voice assisted technologies were generally preferred over gesture-based, this is likely to reflect the increasing availability of voice-controlled devices, i.e. Alexa, Cortana and Siri. Integration of TTs within radiology are not new and such devices were reported to be available by 16% of respondents. Further details from respondents were not sought within this study and should be considered within future work. This response rate may reflect our study focus which was predominantly around radiography; TT reports within the published literature tend to focus on IR and image viewing[11].

Integration and anticipation of TTs within radiography will depend on many factors. Prior experience of such devices, preferences of manufacturers and service needs will guide future development and implementation. Although reports are limited, research related to the uptake and engagement with Smartphones suggests that capability, motivation and opportunity are the influencing factors[12]. Efficient imaging examinations are a universal goal for all radiographers and imaging departments. Currently, there is a disconnect between the potential for TTs and options available on commercial imaging equipment. Results of this international survey could be used to guide manufacturers in integrating TTs within their imaging equipment.

Several key areas within our research were dominant (**Figs 3 & 4**). Moving equipment into pre-defined positions was popular, this is likely to reflect options that are already available on some current equipment, actioned by remote control or instigated at the acquisition console. Changes to X-ray room environment were also popular, i.e. dimming of the lights, initiating music / distraction techniques. Such tasks are likely to be required when dealing with unexpected events. These many include managing uncooperative patients or when aligning image receptors under trolleys or visualising the collimation field on patients with non-hospital clothing.

From our study, voice TTs are favoured over gesture-based. This is likely to result from flexibility issues since voice activated TTs can be accessed anywhere within the examination room. Gesture-based TTs would require the radiographer to face or gesture towards a camera. For maximum utility, we would suggest that this technology would need to follow the radiographer through different aspects of the imaging examination or multiple cameras would need to be setup within the room.

It should be noted that there could be a potential culture issue regarding the acceptance and use of TTs within clinical practice. By way of reference, we have seen some of the commentary regarding the inclusion of machine learning, deep learning and artificial intelligence within medical imaging[13]. Further consideration is needed as to whether TTs would be considered friend of foe and also whether there could be privacy or ethical issues from using such technologies.

Limitations

Several limitations exist within this study. Participation was entirely voluntary and based on recruitment through the EFRS and the ECR 2020 online conference. The questionnaire was online and deployed in English, this may have biased responses to only those who are proficient in English and those who have internet access. Our study design was for an international study, to some extent this was achieved in responses from 23 countries (five continents). Responses were particularly focused around Europe and were absent from South America. As authors, we would postulate that it is unlikely that radiographic practices and the availability of imaging technology would be substantially different in South America. It would, however, add to study findings if future studies could include responses from this region. Participants were asked to consider their perceptions of where TTs may be useful when faced with a series of proposals. Techniques, such as Dephi methods, could have been used to establish a consensus as to the priority areas for TT development within radiography. This should be the focus of future studies and should involve industrial partners.

Recommendations

Academics, clinicians, and manufacturers should carefully consider the findings from this study and work collaboratively to plan the effective integration of TTs within radiography. Such technologies are readily available and should not be too difficult to integrate with modern X-ray units. Any steps to include TTs within imaging examinations should be followed with robust evaluations, which include representatives from industry, to ensure that there are tangible benefits for patients and practitioners. It is possible to implement TTs within current X-ray rooms as a method for controlling room lighting, ambient music and distraction devices. Developing TTs which have the potential to control X-ray exposure (either fully or partially) or movement of X-ray equipment and / or the patient should give careful consideration to the health and safety implications. Such considerations may also need to include advice from appropriate national regulatory agencies. Costs are likely to be a factor in the adaption of TTs, some of the described applications are likely to be relatively simply to implement and as such would be unlikely cost prohibitive.

Conclusions

There is growing potential for the inclusion of TTs within general X-ray systems and this should be urgently evaluated. Radiographers appear optimistic regarding the potential for TTs in aiding practice. TTs have the potential for helping optimise radiographic examinations and when combined with future emerging technologies should help change and improve radiographic practices. The inclusion of such technologies should be carefully outlined by appropriate organisations, such recommendations should also guide appropriate evaluations and reporting. Collaboration with equipment manufacturers is urgently required and is essential for effective development, testing and implementation of such technologies.

Acknowledgement

We would like to acknowledge the European Federation of Radiographer Societies (EFRS) for facilitating access to the EFRS 2020 Research Hub which was delivered as part of the European Radiology Congress 2020 Summer Edition. We would also like to thank all of our participants for taking the time to complete the online questionnaire.

Conflict of interest

None.

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