CreaTable Content and Tangible Interaction in Aphasia

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ABSTRACT

Multimedia digital content (combining pictures, text and music) is ubiquitous. The process of creating such content using existing tools typically requires complex, language-laden interactions which pose a challenge for users with aphasia (a language impairment following brain injury). Tangible interactions offer a potential means to address this challenge, however, there has been little work exploring their potential for this purpose. In this paper, we present *CreaTable* – a platform that enables us to explore tangible interaction as a means of supporting digital content creation for people with aphasia. We report details of the co-design of *CreaTable* and findings from a digital creativity workshop. Workshop findings indicated that *CreaTable* enabled people with aphasia to create something they would not otherwise have been able to. We report how users' aphasia profiles affected their experience, describe tensions in collaborative content creation and provide insight into more accessible content creation using tangibles.

Author Keywords

Aphasia, tangible user interfaces, creativity, content creation, accessibility, multimedia, co-design, creativity support.

INTRODUCTION

Creative acts are often evocative; they might allow us to convey thoughts, emotions or rich imagery. They enable us to express ideas we might not otherwise be able to express through traditional communication routes, such as speaking and writing, alone. Further to the expressive benefits of creativity, being creative has also been shown to afford improved mental well-being and self-esteem [15, 23]. We might use more than one modality when being creative – for example, we might sing a song and gesture simultaneously to say something more than we could say with either modality on its own. Allowing for multiple modalities, including non-language modalities, and the creation of multiple types of media, offers an opportunity for people with language impairments to be expressive. For example, people with aphasia (a language impairment following brain injury) might engage in expressive activities such as the creation of physical forms [38], photography [39] or singing [40] with fewer barriers than they face with traditional communication.

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The digital age offers a range of tools giving individuals rich capabilities for creating and distributing multimedia digital content. Such creative digital technologies (video editing tools, social media apps, etc.) might appear to have the potential to support people with language impairments to engage in creative acts. However, these technologies are often not accessible [6, 13, 25] due to their highly-textual, multi-step nature [25]. Therefore, while creativity might offer people with speech and language impairments an alternative means to expression, current digital creation tools do not adequately support this. Tangible systems, combining physicality with digital interactivity [19, 32], may have potential in this context because they map to innate human abilities – interacting with the 'real world' is *natural* for us – reducing the need for language-based interactions.

Previous work suggests that tangible systems have enabled people with a range of disabilities to engage more effectively with computers [37, 54, 58]. Koushik et al. [37], for example, created a tangible block-based game enabling blind programmers to generate programming logic by creating audio stories. Tangible systems offer an intuitive input modality. This presents an opportunity to create technologies more accessible to people with aphasia and to address some of the challenges these users face with digital content creation. Tangibles however, have not yet been used for this purpose. The overarching aim of the work presented here was to design an approach and a technology which would support people with severe aphasia to create expressive digital content they might otherwise be unable to create. In this paper, we report a tool that enables people with aphasia to create multimedia compositions without the challenges associated with mainstream content creation tools, via tangible interaction. Our work makes three main contributions:

- *CreaTable*: A novel tangible platform for people with aphasia to create and curate digital content;
- Insights from the process of co-designing *CreaTable* where we worked with four people with severe aphasia;
- Findings from an evaluative content creation workshop where we investigated whether people with aphasia could use *CreaTable* successfully, how they collaborated and how their aphasia affected their experience.

BACKGROUND

Tangibles and Disability

Tangible systems (or 'user interfaces') offer one-to-one mapping of physical to digital information. The benefits that this mapping affords are numerous. Such systems have been shown

to offer reduced need for visual attention [33], improved interaction efficiency [59], more nuanced control [60] and more effective object manipulation for tasks [59] when compared to standard computer interface counterparts (e.g. mouse, keyboard, touchscreen). Due to this direct mapping, tangible systems have been widely explored with people with a range of impairments as a means for them to interact with technology more resourcefully. Falcao et al. [18], for instance, explored how tangible technologies might enable children with intellectual disabilities to 'take the initiative' more with technology. Tangible systems have also enabled users with visual impairments to engage with non-visual programming interfaces [37, 58], allowed unique 'single purpose' custom form factors to aid children with autism [54] and been shown as effective tools to support language skill development [27, 26].

Of particular relevance to the work reported here, there has been some limited consideration of tangibles for people with speech and language impairments. Taking on concepts from speech and language therapy, where physical artefacts such as paper and props are key for communication (e.g. [10]), work such as that by Piper et al. [48] considers how such 'traditional' materials might be augmented with digital media, such as audio, via digital pen technology. Work by Herault et al. [28] also describes the customisation of physical objects to enable speech and language therapists (SLTs) to link written words and concepts to physical forms. Finally, Al Mahmud et al. [2] describe a tangible messaging system designed with people with aphasia to communicate remotely using post-its and webcams. While such work mainly focuses on therapeutic rehabilitation, we aim to enable creativity and expression.

Tangibles for Content Creation

Many creative techniques – plucking a string to produce a note or painting with a brush – are inherently tangible. The intuitive nature of these interactions can be lost when transferring such processes to the digital domain. The digital domain, however, also offers previously unimaginable possibilities for content creation and sharing. Research has unsurprisingly focused on creating the best of both worlds, via tangible systems. For music, research has considered how we might arrange blocks into musical compositions [16]. Work such as ReacTable [34] affords collaborative composition of music on a table using puck-like tangible objects [35].

Tangible systems have also been considered in the visual arts domain. A ubiquitous example of this is the digital stylus, which emulates the affordances of pens and pencils. Work has explored how this might be extended by using physical objects as input [36] and supporting digital painting [53, 55]. Research has also explored how physical interactions might be used to support children in story-telling [17, 52, 62].

In video production, Bartindale et al. [7] discuss StoryCrate, a tangible system designed to help film production teams to storyboard scenes while on location by allowing them to interact with video content just after capture. Here, tangible controls enable different production techniques (e.g., mark-in/out, zoom). Finally, with a focus on post-production, Zigelbaum et al. [64] describe a tangible system for sequencing video in which pocket PCs can be arranged to form an overall video sequence. In our work, we also consider tangibles for multimedia creation. However, the work presented here considers tools designed with and for people with aphasia for accessible *expression*, as opposed to tools for video professionals.

Aphasia and Content Creation

We now consider aphasia and how it might affect content creation. Aphasia is an acquired language impairment. It is most commonly caused by a stroke, but can be caused by other forms of damage to the language regions of the brain [5]. It can affect reading, writing, speech and comprehension. The aspects of language affected can vary significantly between people. Some people might be able to produce only very limited amounts of speech whilst retaining good levels of auditory comprehension. Others might retain good speech but acquire deficits in writing. Aphasia is often considered an invisible condition – although one third of people who have a stroke are affected by aphasia, less than 10% of the population know what it is [14]. As the population ages and the odds of surviving a stroke increase, the probability of a given person being affected directly or indirectly by aphasia, is increasing year-on-year. Therefore, a growing number of individuals will be faced with significantly reduced opportunities to express their creative potential due to language barriers.

Technology for digital content creation was not created with language impairments in mind, making it challenging for people with aphasia to fulfil their expressive potential. Increasingly, work has focused on supporting creative processes in a range of user groups (c.f. Frich et al.'s survey paper [20]). For instance, creativity support tools for creative writing might utilise time constraints [9], or algorithmic assistance for metaphor [22]. These approaches are, however, likely not suitable for people with aphasia. Aphasia literature indicates that implicit language demands inherent to modern technology sometimes present impassable barriers for some [12, 24, 42, 50] to engage with 'mainstream' technologies. Many widely adopted social media tools, for example, present a number of barriers [25]. However, people with aphasia show a desire to produce online content [29]. They often require support to use existing tools however, e.g. by having their partner manage their account and content [57], or find themselves only able to engage with more visual aspects of social media [29]. Technologists have also considered how we might design social media networks around people with aphasia, to distribute media and connect with others online [43, 56].

In non-digital creativity, Lazar et al. [38] investigated how art therapy affords new creative opportunities for people with complex speech and language needs. People with aphasia can also benefit from having people to support them when being creative. Chris Ireland – a poet with aphasia – for example, is supported by an SLT friend who does not have aphasia [30, 31]. More broadly, art therapy has been shown to have positive benefits on expression in people with aphasia [38, 39, 40] as these approaches can avoid language challenges and therefore imbue their other competencies.

Whilst tools exist to make interactions with technology more accessible for people with aphasia, there is currently little available in the way of *artistically expressive content creation*

tools. Existing tools, for instance, focus on methods to retrain lost vocabulary [47], assist conversation [61], plan activities [44] or train communicative gestures [51]. While some work has considered how people might communicate through digital content such as photos [1, 3, 4] and textual content online [41, 43], these are mostly for *functional* purposes. Limited work considers creativity. We have previously presented *MakeWrite*, an app to support people with aphasia to produce creative writing [46]. This tablet-based app supported content creation in one medium (text) and was created to meet the needs of people with mild to moderate aphasia. Against this context, we present a tangible platform, *CreaTable*, and a media sequencer app, that we have developed to support people with severe aphasia (i.e. people with very limited expressive and/or receptive language in either spoken and/or written form) in creating expressive, multimedia digital content.

CREATABLE AND CREATABLE MEDIA SEQUENCER

CreaTable is a tangible platform for creating and curating multimedia content. It consists of a table where tangible objects are arranged by users. A webcam and fiducial-based recognition system detect the position of the objects to create an equivalent digital representation.

We have developed a media sequencer app that uses *CreaTable* to sequence and play multimedia content. Figure 1 shows *CreaTable* in the foreground and two screens used by the media sequencer app in the background (called the *Arrange* screen and the *Play* screen). Each tangible object on the table represents a piece of multimedia content: either a picture, a piece of music, a musical note, an emoji or a word. The equivalent static digital representation of the objects is displayed on the left-hand *Arrange* screen. See the accompanying video figure for a demonstration.

Similar to video editing software, the media sequencer app can also "play" the content. In play mode, a virtual play-head moves across the content, playing each piece of content that it meets. A piece of content is played either by presenting it on the right-hand *Play* screen (for visual and textual content), or by playing a sound (for audio content). The play-head is displayed as a light on the *CreaTable* via a programmable LED strip (see 'position indicator' in Fig. 1) and as a line on the *Arrange* screen. Once the play-head reaches the end of the content, it returns to the beginning and continually loops. The play-head can move either left-to-right or right-to-left and is controlled by a knob at the front of the table ('speed and direction control' in Fig. 1). Twisting the knob in a given direction speeds up the play-head in that direction. Moving the knob to a central position stops the play-head.

Figure 2 shows the tangible objects used in the media sequencer app. These are played in different ways. Pictures (Fig. 2, a) are displayed as full-screen pictures on the *Play* screen. Pieces of music (Fig. 2, b) are played aloud in a continual loop. Musical notes (Fig. 2, c) are played aloud as single musical notes, arpeggios or chords, with the vertical position of the tangible object on the table changing the pitch of the note. Emojis (Fig. 2, d) are displayed on the *Play* screen in the same position as the tangible object occupies on the table, e.g. if placed on the top right of *CreaTable*, they are rendered in the top right of the *Play* screen. Similarly, words (Fig. 2, e) are displayed on the *Play* screen in a position that correlates to their physical position on the CreaTable surface.

While most of the tangible objects have a single digital equivalent, there are two special 5-sided objects (Fig. 2, f and g). These allow the user to select additional content through indirect mappings. Tangible object f) can be rotated to choose one of five words; tangible object g) can be rotated to select one of five images. These controls were implemented to overcome the challenge of a potentially overwhelming number of tangible objects if there is an object for every piece of content.

The user journey for the *CreaTable* media sequencer app is as follows: the user selects tangible objects and places them on *CreaTable* to create a multimedia composition. They can immediately see the equivalent static digital version on the *Arrange* screen. The user can then 'play' the content by manipulating the play-head knob, viewing visual content on the *Play* screen and listening to audio content.

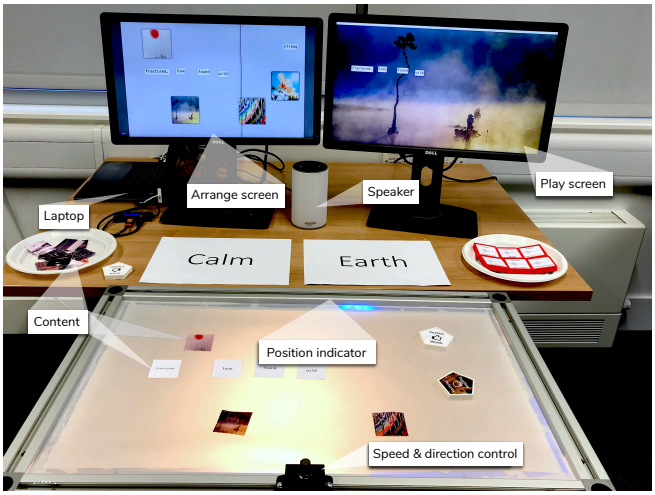

Figure 1. The CreaTable media sequencer system.

Technical and Control Details

CreaTable measures 780mm in width, 490mm in depth and 715mm in height. It is constructed from a 10mm thick perspex surface mounted within an aluminium extrusion frame. The table surface is 700m in width by 410mm in depth (aspect ratio $\approx$ 16:9). Fig. 4 shows the technical components of the system. The user interacts by moving tangible objects on the surface of *CreaTable*. Attached to the bottom of all tangibles is a fiducial marker which is tracked with the reacTIVision toolkit [34] via a webcam mounted below the table's surface. Similar to [34], tracing paper on the perspex surface prevents users from seeing through the perspex, whilst allowing for object tracking from below. The fiducial data is processed in the Processing environment, via the TUIO framework. User input from a potentiometer mounted on the front of the *CreaTable* is sent to the laptop via an Arduino Uno microcontroller to control the play-head and the play-head position is displayed using a programmable LED strip.

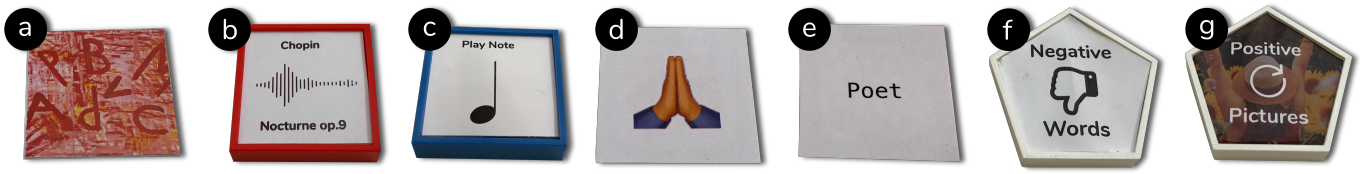

Figure 2. Tangible objects for CreaTable: a) a painting, b) a piece of music, c) an individual musical note, d) an emoji, e) a single word, f) a rotational series of words, g) a rotational series of pictures. The tangible objects take a number of physical forms: printed paper (a, d), fridge magnets (e), and 3D printed shells with (interchangeable) pieces of card slotted in (b, c).

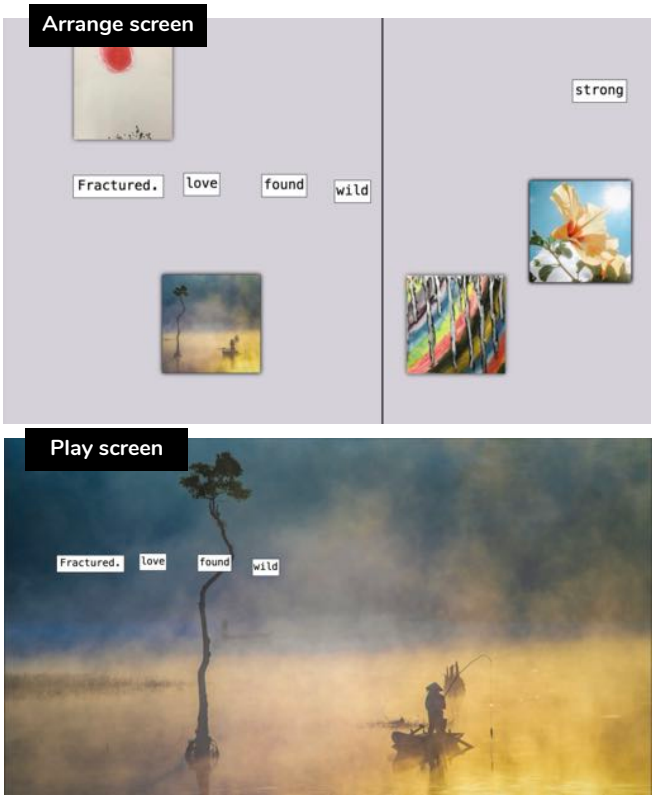

Figure 3. The *Arrange* and *Play* screens from Figure 1. The *Arrange* screen shows the static arrangement of content. The *Play* screen shows the content being played. Play-head movement is left to right.

CO-DESIGN OF CREATABLE

We now report the co-design process that resulted in *CreaTable* and the media sequencer app with the goal of showing the significant contribution of co-design in shaping the system. As the table and the app were designed simutaneously, we refer to the combination as *CreaTable* here. Four people with aphasia were employed as co-designers. All four had moderate to severe aphasic language difficulties as a result of a stroke, and limb weakness (hemiplegia) affecting their right arm. Three used a stick to walk. Ages ranged from 31 to 62 years old.

Three co-design workshops were conducted, each lasting 2.5 hours. The co-designers with aphasia worked alongside co-designer researchers to ideate and provide feedback on ideas and prototypes. Their participation was facilitated through co-design techniques adapted for people with aphasia, such as those reported by Wilson et al. [63]. The sessions were mostly group-based, but also included some individual use of technologies. Co-created personas, which have previously been used to co-design effectively with people with aphasia, Parkinson's disease and dementia [11, 45], were used extensively to broaden the demographic of the co-designers beyond those in the room and to introduce the co-designers to the process of 'doing design' together.

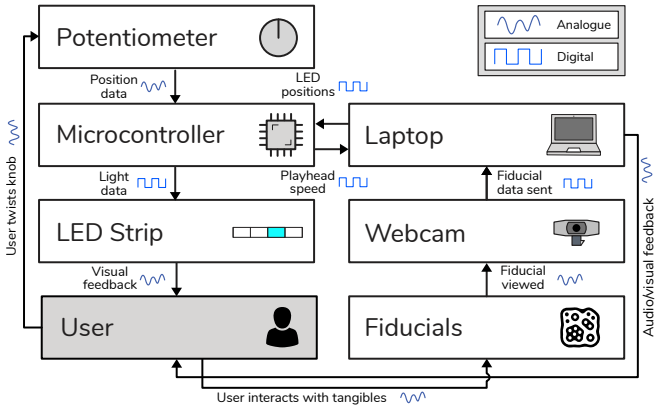

Figure 4. Flow diagram of CreaTable.

Workshop 1: Introduction to Tangibility

Co-design workshop 1 focused on exploring the types of digital content that the co-designers with aphasia might want to create and the potential of a tangible approach for creating it. High-fidelity prototyping techniques have previously been reported to be more effective than low-fidelity techniques (such as paper prototypes and sketches) for people with aphasia. Therefore we adopted this approach and used a specific tangible system to support the discussion [21, 46, 63].

We developed and used a tangible system for composing simple melodies, similar to [16]. This consisted of a webcam positioned above a desk where coloured 3D-printed blocks were placed. Simple blob-tracking was used to determine the position of the blocks. Each block represented a single musical note. The vertical position of a block controlled the pitch of the note. The system continually 'played' the arrangement of blocks using a virtual 'play-head' that moved across the desk from left to right and then looped back to the beginning. The blocks varied in shape and size so that we could explore their acceptability to the co-designers given their limited dexterity.

Co-designers with aphasia were introduced to the tangible system and then spent some time creating melodies. They were supported in a discussion to provide feedback and make constructive suggestions for future developments. Co-designers found the tangibility to be engaging and accessible. All the tangible blocks of varied sizes and shapes were usable and acceptable. The looping feature enabled co-designers to initiate a fledgling idea and then interactively refine it; this was positively received. We probed which other media types (other than music) might be interesting to use with such a system. One co-designer – an accomplished artist – was keen to explore how he might incorporate his paintings with other media types, specifically music. Other combinations of media were also discussed (e.g. music + lyrics = song). This was positively received – the general consensus was "let's see".

Workshop 2: Refinement of Tangible Prototype

Based on the input from the co-designers, we refined the tangible system for workshop 2. Media types suggested by co-designers were added – blocks were added to represent words and pictures. This meant that users could now compose multimedia content consisting of music, pictures and words. As before, the composition was 'played' by the system. A display was added to 'play' the pictures and words. The pictures were 'played' by displaying them full screen on the screen. Words were 'played' by displaying them in their position, superimposed on the pictures.

Co-designers were again supported to provide feedback, this time focusing on the new media types. Feedback indicated that they enjoyed exploring the different images and tried to 'match' them to the musical notes. They matched these both temporally (i.e. synchronising them), and aesthetically. However, the music created with the system was deemed too simple to satisfactorily complement the images. There was a desire to include pre-recorded music and to create more sophisticated musical sequences. The feedback about the words was mixed. One co-designer had a particular dislike of words due to the challenges he experiences with reading, while others were interested in further exploration of words.

The visual media prompted other discussions including whether the system should be used for creating personal content or more general artistic purposes. One co-designer wished to use the system to curate her photos from a recent holiday and complement them with other media. Another co-designer wished to use the system to display and match his paintings to music. To further explore this topic, a discussion around *where* such content might be displayed was initiated. Some co-designers responded positively to the idea of sharing their work in a gallery, others saw the tangible system as a more personal creation tool, for sharing photos with family and friends. Others expressed interest in both.

Workshop 3: Conveying Sentiment

The prototype was further refined in preparation for the third workshop. Building on the positive feedback and suggestions, a first version of *CreaTable* was developed. The solid desktop was replaced with a sheet of perspex, the webcam was moved from above to below the tangible objects and fiducial markers were placed on the undersides of the objects. This resulted in less occlusion from the users' hands and afforded a more discreet tracking approach because users could not see the markers. A programmable LED strip was incorporated into the table to show the position of the play-head and a second display (the *Arrange* screen) was introduced to show the content in static digital form. We saw a need in workshop 2 to offer the user more control and complexity. Therefore, rather than playing the content at a set speed and in a fixed left-right sequence, the speed and direction control knob was added to the front of the table.

Based on discussions in workshop 2, additional media types were introduced (more pictures, pieces of music, more complex musical notes (e.g. arpeggios, emojis and words). Some of the pictures were contributed by co-designers. The tangible objects were a mixture of printed cards and 3D printed shells with slots for content cards (Fig. 2, a, b, c, d and e).

In workshop 3, co-designers used the tangible system to create content related to specific 'themes'. Each theme was presented as a set of words: "happiness, sun, fun"; "love and friendship" and "darkness, anger, sea". We found that it was best to do this as a structured activity, breaking the process into discrete tasks to limit challenge and working with one media type at a time. Although a wide choice of content was clearly important to the co-designers, they had problems physically reaching all of the tangible objects on display across the table. This was exacerbated by their hemiplegia.

Discussions about how to address the challenge of having too many tangible objects suggested that it might be useful to reduce the quantity of physical objects, while still allowing for lots of easy-to-access content. The co-design team settled on the idea of 'grouping' different pieces of content into one tangible object and the user doing some form of manipulation to select the content. Acceptable manipulations were twist interactions and moving the objects up and down on the table. This led to a final modification, the introduction of 5-sided selector objects, and hence the current *CreaTable* prototype.

DIGITAL CONTENT CREATION WORKSHOP

To investigate the efficacy and the possibilities of *CreaTable* for enabling people with aphasia to create digital content, we ran a digital content creation workshop at a local aphasia drop-in clinic. This workshop was undertaken within the ethics framework of City, University of London. We aimed to establish (a) whether people with aphasia would be able to create content using *CreaTable*, (b) what people would think about working collaboratively to use *CreaTable* and (c) how people would perceive ownership of any content created. Clinic attendees could choose whether to participate in the workshop or to continue with their regular activities. One attendee was excluded due to his role as a co-designer. Beyond this, the workshop was open to all attendees – therefore participants comprised a range of aphasic profiles and other physical impairments commonly associated with stroke. Data collection was facilitated by four qualified SLTs and two student SLTs (SSLTs). Two technology researchers further facilitated the session and managed the *CreaTable* prototype and the video and audio data capture.

Procedure

The session commenced with information giving and consent form completion by all attendees wishing to take part. This was followed by completion of a background information report and then use of *CreaTable* in small groups. After this, participants were supported to complete a feedback sheet. Finally, at the very end of the session, a recital of compositions created by each group was presented to all drop-in attendees and accompanied by a full-group discussion and reflection.

Participants were supported to access the information sheet, consent and feedback forms by the SLTs and SSLTs. Forms were created to be aphasia-accessible, incorporating both visual rating scales and pictures to accompany question text. Details of aphasia were captured through facilitated self-report of each individual's perceived difficulties with reading, writing, speaking and listening. Specific examples were presented to facilitate participants to self-report. To understand a participant's perceived ability in each domain, they were asked if they could undertake given (hypothetical) activities, in decreasing order of difficulty. For example, for reading they were asked if they could read: 'Long-text – like a story'; 'a letter/email to a friend'; 'Simple sentences'; 'Some single words'; 'my name'.

Next, participants used *CreaTable* in groups: two groups of four people (Groups 1 and 3) and one group of three people (Group 2) in a separate room alongside two researchers. Both researchers – an SLT researcher and a technology researcher – had extensive experience of using digital technologies with people with aphasia. Participants were positioned around three sides of the *CreaTable*, taking any mobility constraints into consideration. Participants were asked to select from unseen sheets of paper to randomly choose a 'theme' for the content they would be creating. The two selected paper sheets – each showing a single word in large, bold text – were then placed near the prototype to act as visual cues and reminders throughout the creation process. Group 1 chose 'Surprise' and 'Fire'; Group 2 chose 'Earth' and 'Happy'; Group 3 chose 'Calm' and 'Wind'(see the words 'Calm' and 'Earth' in Fig. 1).

Participants were next introduced to *CreaTable*. Through initial demonstration with picture objects, they were shown that when the tangible objects were placed on the table, the content appeared on the *Arrange* screen. They were then shown how content could be played on the *Play* screen using the play-head. Once the concept of playing pictures was understood, other content types were introduced one-by-one, as the co-design sessions indicated the simultaneous introduction of many content types could be overwhelming. The participants were then encouraged to create a piece of content on the *Play* screen to 'match' their two thematic words. The SLT researcher prompted engagement with the objects and the table. Participants were also free to engage with objects under their own initiative, i.e. unprompted. The sessions were video-recorded and the copies were taken of the content that was created.

Managing and Introducing Content

Given the time constraints of running the session, and the previous complexities faced with content in the co-design sessions, we limited the number of tangible objects available to the groups. We opted to not provide emoji or musical notes and we limited the content to around 15 pictures, including a variety of stock photos of varying aesthetics and selected paintings from the artist co-designer. Similarly, around 15 words were included (e.g. "Poet", "garden", "Cat"). In addition, we included 5 words and 5 pictures for each theme in the 5-sided selector objects. We included 6 varied pieces of music, again to avoid choice paralysis. Finally, to reduce the cognitive and physical burdens on accessing content, and to provide a familiar approach, we offered the tangible objects on a tray, with smaller plates where objects could be easily grouped and passed around (see Fig. 5).

Figure 5. Tangible objects on trays and plates.

Participants

Eleven people participated in the digital content creation workshop. Ten had a clinical diagnosis of aphasia; one (P11) had self-reported communication difficulties following her stroke but no clinical diagnosis. People were allocated to groups on a convenience basis (i.e. those who were interested, available and had consented at the time that the group was starting). Participant demographics and aphasia-related information are shown in Table 1. Six participants were female and 5 male. Ages ranged from 49 to 75, with an average of 60.3 (SD = 7).

Participants reported varying language difficulties – representing a relatively typical sample of a group of people with aphasia. Seven participants reported some form of difficulty with reading, six with writing, nine with speaking and three with understanding. Most participants (7) reported some kind of physical difficulty – predominantly one-sided weakness/paralysis (hemiplegia/hemiparesis) as a result of their stroke, implying limited use of their dominant hand, or a mobility difficulty.

Results: Final Content Created

An example of the final content produced can be seen in Fig. 6. Content analysis of the final content showed that Group 1 (Surprise and Fire) focused more on the word 'surprise'. They did so through humour, first by presenting a picture of a lamb, then presenting a picture of a dead animal skull, coupled with the word 'shock'. The music chosen here was Greig's Morning Mood. This piece of music is often used in audio for visual media to symbolise mornings and the rising sun.

Group 2 (Earth, Happy) created three scenes from three photographs, inspired by a poetic phrase they chose after experimentation: "*famished love garden*'. The first scene coupled the word 'famished' with an image of an evening fishing scene, showing a solitary fisherman on a misty lake. The second scene combined 'love' with an image of a woman jumping on a bed. Finally, when the entire phrase is presented with the

Figure 6. Four screenshots from Group 3's piece of content. Their themes were 'calm' and 'wind'. The words arranged over the images and presented sequentially are: 'wild' 'angry' 'quiet' 'strong' 'love'. The music played was Acoustic Breeze.

P	M/F	G	Age	Difficulties reading	Difficulties writing	Difficulties speaking	Difficulties understanding	Physical difficulties
1	F	1	66	Books. Magazines. Road Signs. Menus	Own name	For a long time	None	Right hand & leg
2	M	1	61	Books	Own name	For a long time	None	Right hand
3	F	1	57	Road Signs	None	None	The radio. The TV. A conversation	None
4	M	1	57	None	None	A few words or more	Telephone conversation	None
5	M	2	60	Books. Magazines	Long-texts	For a long time	None	Right hand
6	M	2	49	Menus	Long-text. Letter/email	None	None	Right hand
7	M	2	75	None	Simple sentences	A few words or more	None	None
8	F	3	60	None	None	For a long time	None	Right hand
9	F	3	62	Books	None	A few words or more	None	None
10	F	3	52	Books. Magazines. Road Signs. Menus	Simple sentences	For a long or short time	The radio. Telephone conversation	One hand
11	F	3	65	None	None	For a long time	None	Right hand

Table 1. Participants' gender, group (G), age and difficulties as a result of their stroke.

final word 'garden', a man is shown looking out into a lake at dusk. For music they chose Chopin's Op .9 no 2., which has a down-tempo, and is a somewhat solemn, delicate piece.

Figure 7. Four participants collaborating to make some content. One participant (left) is adding a piece of music.

Group 3 (Calm, Wind), shown in Fig. 6, first took one of the artist co-designer's paintings. They selected the words 'wild' and 'angry' to match this. Then, selecting the same fishing scene as Group 2 chose, they added the word 'quiet'. Then they matched the word 'strong' to a pair of skiers climbing a mountain and finally used the sea to match the word 'love'. The music chosen was Acoustic Breeze, which its composer describes as "*[...] music with a soft and mellow mood*".

In the sessions, the participants used the looping control feature of *CreaTable* to go back and forth and stop on specific content. However, for the purposes of demonstrating their work to others in the recital, we asked the participants to make a sequence they wanted to share. The average duration was approximately 20 seconds. Group 1 used all four 5-sided objects (words and pictures for both themes) in their final piece, group 2 used none, group 3 used two (for theme words).

Tangible Interactions

Video data from the three group sessions were analysed to capture the number of prompted and unprompted tangible interactions undertaken by participants (Table 2). A prompted interaction was defined as a participant's physical movement of a tangible object following an explicit verbal prompt from a researcher, an unprompted interaction was defined as a physical movement of a tangible object without explicit instruction from a researcher. Ten participants engaged in both prompted and unprompted tangible interactions with *CreaTable*. One participant (P1) undertook prompted interactions only. The lowest number of interactions for an individual participant was 5, the highest was 24.

Participant	Interactions	Prompted	Unprompted
1	5	100% (5)	(0%) 0
2	24	29% (7)	71% (17)
3	15	47% (7)	53% (8)
4	8	75% (6)	25% (2)
Group 1 Total	**52**	**48% (25)**	**52% (27)**
5	9	67% (6)	33% (3)
6	11	45% (5)	55% (6)
7	18	39% (7)	61% (11)
Group 2 Total	**38**	**47% (18)**	**53% (20)**
8	6	83% (5)	17% (1)
9	15	47% (7)	53% (8)
10	8	75% (6)	25% (2)
11	7	86% (6)	14% (1)
Group 3 Total	**36**	**67% (24)**	**33% (12)**

Table 2. Tangible Interactions with CreaTable, Percentage Prompted and Unprompted. Presented by Participant and by Group.

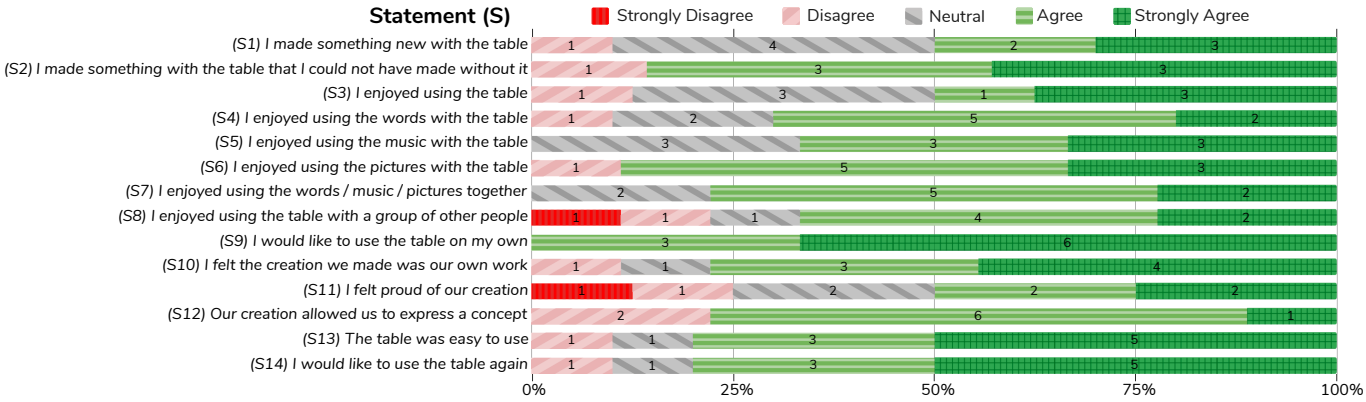

Figure 8. Likert responses to statements on feedback sheet (S1 - S14).

At a group level, groups 1 and 2 undertook a roughly equivalent number of prompted and unprompted interactions (25:27, 18:20 respectively). Group 3 undertook mostly prompted interactions, with a lower proportion of unprompted interactions (24:12). At an individual participant level, around half of the participants (6) demonstrated a higher proportion (i.e. more than 50%) of prompted tangible interactions than unprompted interactions. The remainder demonstrated a higher proportion of unprompted than prompted interactions. Each group had a mix of low engagement participants (i.e. those mostly responding to prompts) and high engagement participants (those who mostly self-initiated interactions). However, as previously stated, every single participant undertook a minimum of 5 tangible interactions.

To illustrate the manner of tangible interaction further, some specific participant examples will now be reported. Participant 7 (Group 2) demonstrated a comparatively high proportion of unprompted interactions (61%). Analysis of these interactions revealed repeated engagement with objects as a means of making sense of their effect on the system. For example, at 6min13s - 6min26s in the group 2 session video, P7 is observed repeatedly moving a picture object in different directions across *CreaTable* whilst gazing intently at the *Arrange* screen. In response to observing the equivalent digital representation shift correspondingly along the x and y axes, he uttered: "*yes*" [moves selected picture object around table] "*right*", "*yes*", [sits back in chair] "*yeah*". P7 demonstrated similar engagements with both the play-head control knob and the picture pentagon, responding to the researcher's question "*Is there one particular picture you're looking for [P7]?*", as he manipulated and rotated the picture pentagon, with "*No, I just..." [continues rotating the block and watching the screen]. Researcher: "Just giving it a try?". P7: "Just..." [continues rotating and watching]. Researcher: "Exploring it?". P7: "Yeah"*. Another highly engaged participant, P2, in contrast used unprompted interactions to refine and modify the sequence of content, repeatedly returning to the play-head control to adjust the speed and order of presented pictures and words as music was played and relocating and re-ordering word objects to fine-tune their presentation.

Results: Subjective Feedback Forms

The post-study Likert data from the statements on the feedback sheet are shown in Fig. 8 (S1 – S14). We report these descriptive statistics alongside the qualitative data captured on the forms. We received a total of 126 responses from the participants; one participant (P8) refused to use the Likert scales and others missed some questions. Overall, a high proportion – ∼73% – of respondents agreed (∼38%) or strongly agreed (∼35%) with each statement, indicating a generally positive overall response to their experience with *CreaTable*. Negative responses made up ∼11% of all responses, with ∼9% of statements 'disagreeing' and ∼2% 'strongly disagreeing'. Neutral statements made up the rest of the ∼16% of responses.

With regards to general responses, there were 50% positive responses to S1 – half of the participants felt they made something 'new' with the table, one disagreed. This participant (P11) commented they found it "*Challenging to create something with others when their choices don't reflect or gel with mine*". Regarding S2, ∼86% of responses stated that *CreaTable* enabled them to create something that they would be otherwise unable to do. Half of the participants enjoyed their time using the table. One positive respondent described it as "*Fun*" (P10). The main negative response seemed to be regarding the group dynamic – "*Would like to be involved. Better one-to-one than in a group*".

For responses concerning the specific media types (words, music, pictures) we saw varying, but mostly positive, responses to all types. For words, 6 respondents (∼70%) either strongly agreed or agreed that they enjoyed using words. Positive users indicated that they found this aspect "*interesting*" (P1) or generally responded positively "*[enjoyed] love, happy*" (P10). P3 appreciated that a limited number of words were provided when using *CreaTable*, and warned of using more – "*Love. single words good. lot of words no*". The inclusion of music was positively received – ∼67% of participants were positive about music, and nobody negative. P9 noted the representational aspect of the music in contrast to the other media – "*The music added to the whole feel of it. The music represented some of the pictures*". The general universal appeal of music was noted – "*Oh yes, like music*"(P10). Concerns arose around the length of music in contrast to the length of the loop – "*10*

seconds not 2–4 minutes" P5. In addition, some participants also wished to import their own music in future. Pictures were responded to positively – only one participant responded negatively (P11), who wished to incorporate her own content. One participant (P10) expressed strongly that the pictures evoked emotions in her, noting they made her feel strong and determined "*strong...determination...keep going*" and P9 liked how you could "*build on them with the with the words and the music*". Finally, when combining media types, the majority of participants enjoyed this process – ∼78% of respondents either agreed or strongly agreed. Positive comments described how they like how the media combined to make one: "*All tied up together*" (P9) – "*A good one, all together*" (P1).

Regarding group work – tensions arose about using *CreaTable* in a group (S8) for some participants. Although the majority enjoyed working in a group (∼67%), some did not. P11, in particular, was strongly against working in a group. She (P11) noted that the final content did not represent her – "*Doesn't reflect who I am*". Others found the group activity perceptually challenging "*others very talkative*" (P1). Positive comments focused around the diversity of opinions, – "*Nice to have people around you with different opinions*" (P9) – "*Happy yes – different ideas working together*" (P10) – "*Yeah – didn't mind. You choose yours, I choose mine. Okay.*" (P3). Regardless of whether they enjoyed using *CreaTable* in a group – all respondents were interested in using the table on their own. P9 noted how individual use of the tool would afford "*more playing around a lot more choice and try out more things if I was on my own*. However, there were also some reservations about using the tool without support: "*...would only do it here [at drop-in group] not at home*" (P3).

When considering the piece of multimedia content that each group created, they generally felt that it was their group's own work (S10), with ∼78% agreement. The one negative response was from P1, who felt "*just felt out of it*". Regarding how proud the groups felt, this responded to positively 50% of the time. While some in their groups felt it was a great team effort "*I liked what we created. It was sound"* ('sound' is UK/Irish slang for good) and the technology enabled them to do something beyond their ordinary experience/capabilities – "*If you can't speak you can use the technology to use your brain. Reactivate your brain*" (P6). While most (∼78%) felt they were able to express a concept (S13) this participant (P11) again, did not. She found that while *CreaTable* allowed her to be expressive, the group environment did not: "*Yes. My bit*" (participant's underlining). One participant said using the tool made her feel determined to keep going "*determination – keep going. positive*" (P10). Another also noted that they would feel more confident in their second usage "*This was the 1st time. The second I would have been more aware.*" (P9).

Regarding ease of use (S13), this was generally responded to positively, with (∼80% agreement to S13 – ∼50% strong agreement, the direct one-to-one mapping of the tangible objects was seen as a positive aspect: "*You just choose what you want and put it on the table. Simple.*" (P9). One participant did not agree with the statement stating that she found it "*confusing*" (P1). In the 'general' feedback part at the end of the form she noted that she found the use of the app "*Too fast.*". Finally, most participants wanted to use *CreaTable* again: "*Yeah, if it was here [at the drop-in group]*" (P3), others simply responded positively – "*[made feel] strong, enjoyed it (P10)*" – "*Let's do it again!*" (P4). P11, who previously noted how she disliked the group-experience stated: "*Yes, if just me*".

Results: Additional Findings

In the recital, the compositions created by each group were projected onto a large central viewing screen and participants were encouraged to offer their thoughts about the experience and the outputs. Video data of the discussion were transcribed and reviewed for key topics. The following main points emerged from the discussion. Participants expressed a desire for a larger variety of content to choose from. P11 identified that she would be keen to incorporate personalised pictures and music. P2 expressed that he would like to extend the length of the sequenced content based upon the length of the selected piece of music (the current prototype plays the content as a repeating loop over the top of an uninterrupted piece of music). P11 indicated that the process would benefit from an additional preparatory step in advance of sitting down at the table, where group members agree upon what ideas they might like to express with the table and who might be interested in working together. Finally, when asked if and how they might like to share compositions made using CreaTable, there was a strong consensus that participants would be keen to share their creations across a variety of platforms. Potential avenues for sharing the content included through video sharing platforms, via personal social media accounts and in public spaces. Participants identified that they would be keen that compositions could be shared widely and particularly with those who may not have an awareness of aphasia.

Beyond the scope of our initial planned analysis, we also observed interesting behaviours *around* the multimedia creation process. We focus our discussions on Group 3 for brevity, who were able to have conversations while using the tool that they might not have had otherwise. When presented with the pentagon word tile, P11 noticed the word 'shock'. In dark humour, she responded "*Shock. Having strokes is shocking isn't it?*". She then rotated through the different words: "*Anger. having a stroke made me angry as well*". Rotating to 'cold' she then went on to describe an experience of when she saw a movie set in Russia, which made her feel cold. One story from P8 utilised a mix of the media: when the group placed 'Hedwig's Theme' from Harry Potter on the table, P8 used the pictures to tell an alternative story "*The man in the sea [in the picture] is going to Harry Potter*", alluding to the Great Lake which surrounds Hogwarts in the Harry Potter series.

DISCUSSION AND REFLECTION

Efficacy of CreaTable

Tangible interaction data revealed that all participants were able to engage with *CreaTable*. Qualitative feedback further showed that the tangible nature of the tool made it approachable for first-time users. This tangible quality fostered initiative and afforded exploratory and sense-making behaviours that one might not expect from a regular content creation tool,

broadly in-step with the tangibles literature [27, 34, 18]. Instilling such sense-making and exploratory behaviours in design is likely a highly useful characteristic for people with language impairments, especially if they find verbal or written interactions challenging. Likert responses indicated predominantly positive feedback from a range of participants.

Although *CreaTable* was designed with people with severe or moderate aphasia, it was used effectively by people with a range of aphasic difficulties. Participants in the session were all able to make contributions to the final content. Each group appeared to iterate their ideas and eventually present unique multimedia content, displaying their competencies with choosing music, pictures and words to match a theme. We were interested to see the range of expression for each given theme, from language-based poetic work by Group 2, to a piece which utilised witty, dark humour from Group 1 – reflecting artistic variations on what it was to convey concepts using *CreaTable*.

Ownership of Content and Collaborative Use

The participants generally felt the work in their compositions was *theirs* (S10), suggesting they felt they had autonomy in their content creation decisions. This tells us two things. Firstly, the constraints imposed on the session (i.e. the specific themes they were asked to convey and the limited set of tangible objects) did not strongly affect the participants' experience of ownership. Secondly, that they did not feel the technology was automating the creativity for them – a common tension with tools which simplify creative processes, as seen in our previous work [46] and that of Benedetti et al. [8]. This noted, we found tensions around a lack of personal content are still to be negotiated.

In the present system, there is a trade-off between the ownership of the content in group work and the desire for users to include their personal content. This tension was evident in both the co-design sessions and the content creation workshop. While, for the purposes of inclusion in the content creation workshop, we wanted to ensure participants had equal 'ownership' of the content, in future work we will address the desire for personalised content more directly.

While *CreaTable* clearly fostered collaboration, the creative process and the varying levels of aphasia sometimes led to tensions. Most participants reported enjoying using the tool collaboratively, but many were also keen to use it alone. Qualitative feedback from some participants suggested specific tensions in the group environment – e.g., the 'talkative' nature of some in the group introduced barriers. Reported tensions arose from either artistic differences or more aphasia-centred challenges. While group work was undertaken as a collaborative effort, the conveyance of a sentiment or a thought is often – like many artistic processes – a personal affair for some. There were evident differences in the speed that people were able grasp some of the features of *CreaTable*, possibly due to varying levels of understanding across the group. This excluded some members at either end. Our findings here highlight the need for facilitation of the varying needs of people with different profiles, and potentially for more consideration of the way that collaborative groups are matched or formed.

Creation as an Outlet

Regarding sharing, group consensus was that the people wanted to share their content (particularly to raise awareness of aphasia). Reflecting on similar literature on social media and content creation tools for people with aphasia, this is a promising result. Our aforementioned work on poetry tools for people with aphasia [46], for example, suggested that the co-designers of the app were happy to share with family and friends, but not publicly on the internet. It is not understood at present whether this was related to working on content in groups, or whether this was more to do with the content output medium. Future work in this area might aim to understand the specific barriers to people with aphasia becoming active content creators, within current frameworks (e.g. [49]). Finally, we note additional affordances of this process with *CreaTable* beyond the simple creation of content. Challenging and humorous discussions about lived experience arose, facilitated by content within the tool. This indicates that an important outcome of this approach, going forward, might not solely be the content itself, but the *process* of its creation. In future work *CreaTable* might benefit people in creative art therapy workshops (such as those previously discussed [38, 39, 40]) to broach topics and raise confidence through shared goals, ultimately with a collaborative digital output.

CONCLUSION

With increasing numbers of people acquiring stroke-related language impairments and the ever-growing power of online multimedia, the necessity for accessible content tools is increasing. This work provides insight into designing creative tools and techniques that are accessible to people with aphasia, demonstrating that tangible interactions offer promise. We have presented *CreaTable*, a tangible tool designed with and for people with severe aphasia. This work is novel in combining aphasia-accessible tangible content alongside static and dynamic representations. The co-design process proved invaluable in demonstrating the merit, opportunities and methods for exploring tangible interaction as a means to create digital content for people with severe aphasia. An evaluative content creation workshop revealed that the tangible interactions afforded by *CreaTable* enabled people with aphasia to make expressive multimedia content that they would have otherwise been unable to create. Our work also revealed tensions when working collaboratively to make such content and a desire to share the created compositions widely.

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