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"I'm keeping those there, are you?" The role of a new user interface paradigm – Separate Control of Shared Space (SCOSS) – in the collaborative decision-making process

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Abstract

We take a socio-cultural approach to comparing how dual control of a new user interface paradigm – Separate Control of Shared Space (SCOSS) – and dual control of a single user interface can work to mediate the collaborative decision-making process between pairs of children carrying out a multiple categorisation word task on a shared computer. Qualitative analysis focuses on how the interface properties of SCOSS can encourage each child to participate in the task and to represent their own opinions as part of the process of reaching final joint agreement. We conclude by suggesting additional features to improve the content of collaborative conversations and by proposing other contexts that may benefit from this interface.

Keywords: Collaborative learning; Human–computer interface; Elementary education

1. Introduction

In this paper we take a socio-cultural approach to comparing how dual control of a new user interface paradigm – Separate Control of Shared Space (SCOSS) – and dual control of a single user interface can work to mediate the collaborative decision-making process between pairs of children carrying out a multiple categorisation word task on a shared computer. The socio-cultural approach prioritises the social and the mediated nature of learning (e.g. Cole, 1996; Vygotsky, 1978; Wertsch, Tulviste, & Hagstrom, 1993) so that the focus of analysis becomes an "irreducible aggregate of individual (or individuals...) *together with mediational means*" (Wertsch et al., 1993, p. 401). The whole is then greater than the sum of its parts so the investigative focus is on the exploration of individuals-using-technology-in-settings. The focus of our analysis is on the identification of

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potential interface affordances and how these can mediate children's usage of the interface as well as their collaborative behaviours.

Vygotsky (1978) argues that learning can best occur whilst children are operating within their 'zone of proximal development'. He defines this as a conceptual space in which children can learn and develop if they are adequately supported and scaffolded (Wood, Bruner, & Ross, 1976) by an adult or more able peer. This type of support can be achieved when children with differing levels of skill work collaboratively on a joint task, with each child making constructive contributions and learning from each other. The aim of the current study was to assess the effectiveness of the SCOSS interface paradigm in mediating collaborative interactions.

In the next section, we will define our understanding of what it means to 'collaborate' from a socio-cultural perspective. We will then discuss some shortcomings of current interfaces that have been identified in previous work that has focused on the role of computers and computer software in promoting collaboration between learners. We will then introduce our new user interface paradigm – SCOSS – and explain its features. We will go on to describe the current study and conclude with a discussion about its implications for collaborative learning.

1.1. Computer interfaces as tools to mediate collaboration

We wish to draw an important distinction between collaboration and co-operation. We uphold Teasley and Roschelle's (1993) description of collaboration as "a co-ordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (p. 235). This is distinct from co-operation, which they define as "the division of labor among participants ... where each person is responsible for a portion of the problem-solving" (p. 235). A simple example is that of completing a crossword. When the task is collaborative, participants make joint decisions. On the other hand, co-operative completion of a crossword may be when participants divide the task into parts and take responsibility for their own part. They may then come together and fit the parts together. The level of intersubjectivity between participants is likely to be higher in the collaborative setting as both are making an effort to understand the other's ideas and suggestions ('I know that you know', and, 'I know that you know that I know'). Intersubjectivity is likely to be lower in the co-operative setting as each participant completed their own parts of the crossword without explaining their ideas and actions to the other ('I don't know that you know'). This distinction is critical because the terms 'collaboration' and 'co-operation' are frequently used interchangeably in the HCI literature, whereas we argue that they are dissimilar. Our aim is to promote collaborative behaviours.

Even though it is recognised that collaboration is a productive way to learn (e.g. Dillenbourg, 1999; Littleton & Light, 1999), and that argumentation and discussion are important ways of elaborating reasoning (e.g. Howe & Tolmie, 1999; Teasley, 1997), much of the software that is used in classrooms (e.g. educational games) is designed for a single user. Moreover, due to equipment shortages, computers are often shared between pairs or small groups of children and they share access to a single mouse. Children frequently manage this by being co-operative; for example, one child 'thinks' and the other 'types' (Sheingold, Hawkins, & Char, 1990). In this scenario, management of turn-taking occupies a considerable amount of time and effort. It is also possible for one child to avoid relinquishing the mouse to their partner, or for one child to override the work done on their partner's previous turn. Such domination of the task is a common feature of shared computer use in classrooms. With this in mind, several studies have been undertaken that explore the collaborative potential of using multiple mice.

Scott, Shoemaker, and Inkpen (2000) have found that the provision of multiple mice does not improve the likelihood of concurrent interaction between children. We argue that this is because the software interface used in their study allowed only one child to have access to each feature at any one time, thus promoting turn-taking rather than concurrent task activity. Benford et al. (2000) asked children to use the authoring tool KidPad, which has the facility for 'tool-mixing' that allows children to combine each of their tools to create a new colour. They report that children with a mouse each co-operated effectively on task-sharing but that reciprocal discussion was minimal, compared to children who were asked to share a single mouse. We argue that this finding is a function of the KidPad interface and of the task: the children were given the option of distributing task elements between them, which they could then complete separately in parallel. These studies indicate that the provision of multiple mice alone is not enough to diminish the opportunity for co-operative

behaviours and to promote collaborative opportunities. They suggest that if task dominance is to be reduced, it is important for all participants to have access to all task elements simultaneously.

Another area of research that has explored interface design as a support for both collaboration and co-operation is Computer Supported Collaborative Learning (CSCL). Unlike the research discussed above, most work in CSCL focuses on on-line learning. For example, Constantino-Gonzalez, Suthers, and Escamilla de Los Santos (2003) explored the use of separate spaces for supporting simultaneous access to all aspects of a problem-solving task for groups of remote workers. Each user's screen was divided into a private space for private work that was not visible to the group, plus a second space that was accessible by the group and visible to them all. We argue that this interface is likely to afford co-operative working rather than collaborative working, as defined above. The private space makes a portion of each individual's reasoning invisible to the rest of the group: the group may 'not know that X knows some information' and it may therefore be difficult for them to fully understand the basis of X's suggestions to the group. It is also possible for one person to undo or alter another's contribution to the shared space without any recourse to its creator (this was not unique to this study; see also, for example, Suthers, 1999). This is distinct from the SCOSS paradigm, which is explored in the current study described below, where children were co-present, they were free to talk to each other, and each child's space was visible to them both but accessible to only one child. The following section will describe the SCOSS paradigm and explain the ways in which it can mediate the collaborative process.

2. Separate Control Of Shared Space (SCOSS): interface properties and potential collaborative behaviours

The limitations discussed above mean that pairs of children sharing a single computer often exhibit co-operative behaviours because the input and interface to the task is designed for a single user. In other words, the properties of the interface, as perceived by the users, create the possibility for, or afford, certain kinds of behaviour (Laurillard, Stratfold, Luckin, Plowman, & Taylor, 2000). Often, the properties of a single user interface afford (or make it possible for) one child to complete the task without consulting their partner. In an attempt to overcome this, we developed an interface paradigm that gives each user Separate Control Of Shared Space (SCOSS). This is one example of a broader set of principles that define the Task Sharing Framework (see Pearce, Kerawalla, Luckin, Yuill, & Harris, 2005). The core properties of Separate Control of Shared Space (SCOSS) are *the provision of separate control over an identical version of the task for each child, within their own private screen space, that is visible to both participants*. These central properties make it possible for each child to engage with the task because:

- each child can control only their *own* task elements with their *own* mouse;
- the provision of separate input devices enables simultaneous control of both sets of task elements;
- the display of each child's task state on the screen means agreement and disagreement are made visually explicit and that children can use this to resource discussion;
- children can be required to agree with each other by clicking their own 'we agree' button before they can proceed.

To illustrate these properties, a simplified task is shown in Fig. 1. It requires that a pair of children discuss and agree upon the arrangement of three shapes. Each child has their own input device (mouse) that controls elements within their own space on their own half of the screen. The children currently *agree* on the position of the circle and they have each indicated their agreement by clicking their own 'we agree' button. In response, the circle has been filled. However, they *disagree* on the position of the square and the rectangle so these shapes remain unfilled. In this way, both agreement and disagreement are represented on the screen and the children can use this to identify which elements require further discussion.

In the next section we will discuss a study which compared how pairs of children, sharing a single computer with a mouse each used the SCOSS interface or a single user interface whilst completing a word categorisation task. This task was designed to incorporate the properties of the SCOSS interface discussed above and illustrated in Fig. 1. Namely, each child had simultaneous and separate mouse control of their own task words within their own space so that agreement and disagreement could be represented. Analysis focuses on identifying

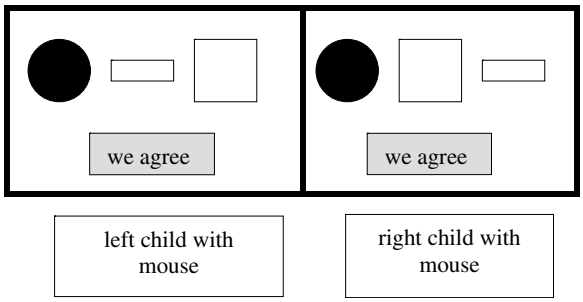

Fig. 1. A schematic representation of a simple task utilising the SCOSS paradigm.

interface properties and the way in which they mediated interface behaviours and the collaborative process.

3. Methodology

3.1. Participants

Sixty-four children in years three and four (aged 7–9 years, Key Stage 2) from four classes in a primary school in East Sussex were given parental consent to participate in a computer-based task. We paired a less able child with a more able peer so as to maximise the opportunity for collaborative scaffolding (Vygotsky, 1978). We carried out a pre-test in which children individually completed a version of the computer task and their performance was scored. We then blindly allocated each child to a partner of the same sex but of differing ability, taking account of advice from their teacher regarding any social mismatches. These 32 pairs of children worked with the same partner throughout all of the activities described below.

3.2. Computer-based task and study design

We iteratively designed, piloted and developed software[1] with children from a different school to that used in the main study. It presented children with a multiple categorisation word task based upon that used by Cartwright (2002) and was chosen because this study was part of the Riddles[2] project, which was exploring children's language awareness skills. Details about the specific linguistic nature of this task are beyond the scope of this paper but, briefly, in each 'round' children were presented with 12 words, one at a time. In each round, the words simultaneously varied on two dimensions: a semantic dimension (e.g. they were either types of animal or types of weather) and a surface feature dimension (e.g. they contained either four or seven letters). The children were asked to find the way in which these two rules applied to the words of each round and to sort the words into a 2×2 array (see Fig. 2). The ability to consider these properties of text simultaneously is said to require cognitive flexibility and the task has been used to improve children's reading comprehension (Cartwright, 2002).

In the main study, the pairs of children completed the word categorisation task using either a single-user interface with a mouse each (Fig. 3a) or the SCOSS paradigm with a mouse each (Fig. 3b) (16 pairs per condition). New words were presented in the 'word pool' and children were required to drag them to one of four different coloured boxes. They then clicked on the agree button/s to get the next new word. Once three words had been correctly placed in a box, they changed colour to match the background and it was no longer possible to move them. Children were also given textual feedback in the 'hints' box which told them whether they were correct, and some children received clues and prompts to help them. The utility of these clues falls outside of the scope of this paper so will not be considered further here.

[1] We thank Rory Graves for programming the software.
[2] The Riddles project was funded by EPSRC grant code GR/R96538.

	4 letters	7 letters
Types of weather	rain snow hail	cyclone thunder drizzle
Types of animal	goat wolf deer	giraffe leopard buffalo

Fig. 2. Multiple categorisation word task.

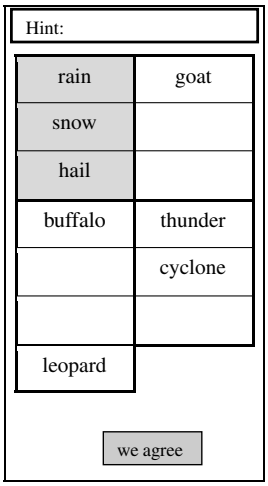

Fig. 3a. Word categorisation task using a single user interface.

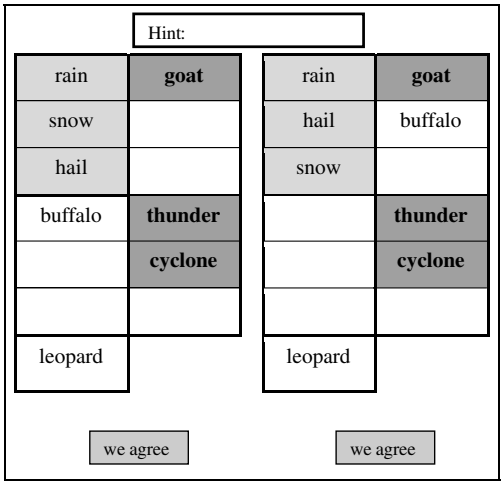

Fig. 3b. Word categorisation task using the SCOSS paradigm.

Examination of Figs. 3a and 3b reveals how pairs of children using the single interface had shared access to a single representation of the task, whilst each child in the SCOSS condition had access to their own representation of the task. In both figures, the words 'rain', 'hail' and 'snow' are correctly placed. A new word, 'leopard' needs to be placed. In Fig. 3b the word 'buffalo' in the white box is disagreed upon and the children need to decide how to agree. The words in dark grey boxes are agreed upon (these were green in reality).

Children working with the single user interface (Fig. 3a) could not benefit from the use of colour to represent dis/agreement as there was only a single, shared representation of the task.

Earlier work on the SCOSS paradigm, that we carried out with pairs of children that had no prior experience of working together, found that often they were reticent and/or hesitant, which was detrimental to good conversation (Kerawalla et al., 2005). We also found that they often did not give explanations for their opinions and were not competent at constructive argument. This supports Pontecorvo and Girardet (1993) who reported that the large majority (81%) of utterances made by small groups of 9-year-olds asked to reach agreement about a historical claim were devoted to espousing their own claims and justifications of them, rather than with building upon each other's ideas. The school in the current study agreed to help children to develop their collaboration and argumentation skills and to get used to working with each other by allocating us three lessons to teach collaboration. It also gave the children time to get used to working with their partner and with the researcher. The first two lessons were drawn directly from lesson plans developed by Wegerif and available freely for download from the internet. The third lesson gave the children an opportunity to practice both reaching agreement and resolving disagreements through explanations and listening to each other (see Kerawalla, 2006). Our aim was not to explore the effectiveness of the lessons in collaboration, although the original authors of these lessons have reported that they are successful (e.g. Wegerif & Dawes, 1997).

Following the lessons described above, the children participated in the computer task with the same partner. The whole session was video recorded and lasted approximately 30–40 min. Firstly, each pair of children read and explained the 'rules for talking' (that their class had generated) from a poster displayed on the wall. Following this, they carried out a word categorisation practice task on paper, to refresh their memory of the task. They then carried out a further practice word categorisation task on a laptop, using a mouse each and either a single-user or SCOSS paradigm. This was followed by three further 'rounds', using the same paradigm, on the laptop and were uninterrupted unless they asked for help. These three rounds were analysed and the findings are described below.

4. Analysis and findings

4.1. Analysis

When analysing how the SCOSS paradigm can mediate collaborative behaviours, we found it was important to attend to what its properties could afford and constrain. Gaver (1991, p. 79) describes affordances as "potentials for action". We have adopted the practice of describing an interface in terms of its 'properties', and these properties become 'affordances' once they have been used to mediate behaviour/s. So, separate spaces are a property of the SCOSS interface, which can potentially afford the representation of disagreement. Once they have been used to do this, the separate spaces can be described as having afforded the visual representation of disagreement. This takes account of both the features of the artefact as well as the individual's interpretation of its potential to meet personal (or pair) needs. It allows for an artefact to be used in more than one way, within the bounds of what it make possible. Laurillard et al. (2000) argue that multimedia is not always used by learners in the way that designers intend because learners and designers perceive the product's properties differently. If we are to design successfully for learning, we must take account of the way in which learners perceive the potential of, and hence use, the resources we produce.

In Table 1 we compare the potential affordances and constraints of a single user interface and the SCOSS paradigm in terms of how single and dual representations of a task and 'we agree' buttons, and control of them, can afford and constrain different ways of using these interfaces and how this could impact upon collaboration. Due to the differences between the interfaces, we hypothesised that they would each give rise to their own set of user behaviours. For example, a single user interface does not include separate spaces, so behaviours afforded by separate spaces will be unique to the SCOSS interface only. For this reason, we did not make statistical comparisons between the numbers of behaviours in each interface condition: one interface simply did not afford particular sorts of behaviour while the other interface did. Our concern was to see what different behaviours were in principle possible in each interface, and to give illustrative examples of where these behaviours occurred in practice. We therefore discuss descriptions of how each interface does or does

Table 1
A comparison of the potential affordances and constraints of a single user interface and the SCOSS paradigm and how they could mediate different user behaviours

	Dual control of single interface	SCOSS paradigm
Number of and control of task representations and 'we agree' buttons	Single set of task elements and single 'we agree' button. Simultaneous control by each user is impossible	Multiple sets of task elements and individual 'we agree' buttons so simultaneous control by each user is possible
	'We agree' clicked by one child to proceed	Both children need to click their own 'we agree' button to proceed
	No indication of who clicked 'we agree'	Each child's 'we agree' button turns green when clicked by that child
	No means of visually depicting agreement and disagreement	Task elements that are agreed upon are green. Other elements retain their original colour
	No means of visually representing final joint agreement	All task elements and each child's 'we agree' button has to be green in order to proceed
Potential affordances and constraints	Changes made by one child will over-ride those made previously by themselves/ their partner: children cannot see both task states concurrently	Children have access to only their own task elements so over-riding is impossible Children can see concurrently their own and their partner's task state
Potential interface behaviours	Turn-taking and co-operation Domination	Children can participate simultaneously Each child can demonstrate their own current and evolving understanding of the task Minimal/no domination at interface level Children can withhold from clicking agree if they need more time or discussion.
Potential collaborative behaviours	Disengagement	Equitable opportunity to contribute to the task process and agreement process at interface level
	Poor collaboration	An opportunity to discuss own and joint understanding of task and agreement: can reflect and reformulate their ideas
	Low level of joint understanding	High level of joint understanding

not afford collaborative behaviours. The construction of Table 1 was useful in identifying the positive behaviours that we would look for in our video data.

The video data was repeatedly scrutinised so as to increase our understanding of how interface behaviours were both constituted by, and constitutive of, collaboration. In the next section, we will explore whether and how each interface feature afforded the behaviours listed in Table 1, and identify any new behaviours that we did not anticipate. We will use transcribed excerpts from the children's conversations to illustrate these points.[3]

4.2. Findings: providing the opportunity for equitable agency at both input and task levels

4.2.1. Equitable opportunity for input: a mouse each

All of the children had their own mouse but the properties of the two different interfaces meant that they could use it in different ways. The children using the single interface exhibited behaviours that were not

[3] We acknowledge that the utterances made by the children often were not very beneficial in terms of reaching an ideal level of joint understanding, because they did not explain their decisions to each other fully. Essentially, the SCOSS paradigm cannot, by itself, scaffold the *content* of collaborative interactions, but can play a role in mediating the *process.*

conducive to joint understanding (Teasley & Roschelle, 1993), some of which have been reported in previous research and discussed above. These were:

- a child not using their mouse at all;
- a single child doing most of the work;
- interrupting and undoing a partner's work;
- moves going unnoticed by a partner;
- clicking on agree to dominate/rush/disrupt a partner;
- parallel working (on separate words simultaneously);
- organised or spontaneous turn-taking.

Excerpt 1 is from a pair of children given dual control of the single user interface. It is a good example of how the provision of dual mice failed to engage both children in the task, which resulted in domination by one child. For current purposes, it is not important to understand why R is making moves, but rather that he is carrying out most of them whilst L looks on.

In this example, the right hand child is carrying out the task without any useful contribution from his partner; he places words and clicks 'we agree' with minimal discussion. This is because it was still possible for only one child to complete the task with their own mouse. This excerpt is a good illustration of why the provision of dual mice is not enough, by itself, to engage both children with the task. In comparison, children using the SCOSS paradigm must both contribute in order for the task to proceed; it is not possible for the above scenario to occur.

4.2.2. Equitable opportunity to participate in the task: separate spaces

The SCOSS paradigm provides each child with private control of their own screen space in which they can work as they wish. The content of each child's space cannot be changed or deleted by their partner. Moreover, each child must participate in the task by moving elements in their own space. These features are all designed so as to maximise the opportunity for each child to contribute to the collaborative decision-making process.

Excerpt 2 is from a pair of children using the SCOSS paradigm. It will be used to demonstrate several points about separate spaces as well as how they facilitate reaching agreement. We are concerned with illustrating how interface properties can afford possible behaviours, so the children's transcribed discussion is supported by visual representations of their computer screen. It is not possible to illustrate every move that the children make, so the dialogue has been divided into chunks with a representation of each child's task state at the *end* of each chunk. We will first present the excerpt and then discuss it further and, where appropriate, compare it with Excerpt 1.

The notation is the same as in excerpt one with the addition of:

- *italicised* transcript indicates disagreement;
- bold transcript indicates words that are **agreed** upon;
- ⟨indicates the left-hand child, and⟩ indicates the right-hand child;
- → task state: indicates the stage in the dialogue that is represented by the depiction of each child's task state (in second column of table).

Actions are in [square brackets]. L = left child. R = right child.
Words in 'inverted commas' refer to task-words on the screen

L	[hands on lap, not using his mouse]
R	[moves 'goat']
R	We agree [clicks agree]
R	Wolf
R	Oh my lord. [moves 'wolf'] O in the middle. O [clicks agree]
R	[moves 'rain'] [clicks agree]
R:	Giraffe [moves 'giraffe'] no [hovers* 'giraffe']
L	No
R	[releases 'giraffe'] No. Thank you [clicks agree]

Excerpt 1. Domination (by R) within the single user interface. *Hovering indicates when a word is clicked on and picked-up by a cursor, and then held over a single or several location/s before being released and placed somewhere.

Task solution:

goat	tornado
wolf	cyclone
deer	thunder
rail	giraffe
hail	buffalo
snow	leopard

The children have placed several words and receive a new word: 'deer'. (→ task state 1)

task state 1

goat	snow		goat	snow	
wolf			wolf		
rain	giraffe		rain	giraffe	
hail	buffalo		hail	buffalo	
tornado			tornado		
deer		<	deer		>

1 < It's that tornado that's the problem isn't it? It's that
2 tornado [moves 'tornado' to grey box] *{'tornado' turns*
3 *white}*.
4 > Yeah. In the box with buffalo [moves 'tornado' in with
5 'buffalo'] {*'tornado' stays white*}
6 < Deer deer deer. Hello dear!
7 > [picks up 'deer' and hovers over top left box] {*'deer'*
8 *turns white*}
9 < Wait wait wait
10 > [places 'deer' in top left] {*'deer' stays white*}
(→ task state 2)

task state 2

goat	snow		goat	snow	
wolf			wolf		
			deer		
rain	giraffe		rain	giraffe	
hail	buffalo		hail	buffalo	
				tornado	
deer tornado		<			>

11 < Has that got anything in there? [points with finger to
12 >'s top left box]
13 > Well it could be right sometimes in a different way
14 < How could it be right?
15 > How could what be right?
16 < That [points with finger to >'s top left box]
17 > Well we don't know
18 < Those are forest creatures [points with finger to >'s top
19 left box]
20 > Goat wolf and deer
21 < Yeah but you've got to look at the letters as well
22 [points with finger to >'s top left box] That's got O, O
23 and that's got EE. And R and D.
24 > [moves 'snow' to bottom left box] *{'snow' turns white*}
(→ task state 3)

task state 3

goat	*snow*		goat		
wolf			wolf		
			deer		
rain	giraffe		rain	giraffe	
hail	buffalo		hail	buffalo	
			snow	*tornado*	
deer tornado		<			>

25 < And those haven't got any letters like that
26 > Rain hail and snow are nearly all the same cos they like
27 come down from the clouds an' all that
28 < Yeah, but hang on. I'm going with you on the forest
29 thing, but the word thing, the sound thing I'm not. Shall
30 we put deer up there?
31 [both move 'deer' to top right box]{**'deer' turns**
32 **green**}
33 > What about the snow?
34 < Well, tornado I'm putting with buffalo [moves
35 'tornado' with 'buffalo'] {**'tornado' turns green**}
36
37 > What about the snow?
38 < Err wait, snow [moves 'snow' to bottom left box]
39 {**'snow' turns green**}
(→ task state 4)

task state 4

goat	deer		goat	deer	
wolf			wolf		
rain	giraffe		rain	giraffe	
hail	buffalo		hail	buffalo	
snow	tornado		snow	tornado	
		<			>

40 > We haven't agreed [clicks own agree] {**his agree**
41 **button turns green**}
42 < Hang on, hang on, think about it. That's got an O in it
43 [points to 'snow']

Excerpt 2. Using the SCOSS paradigm to mediate agreement and disagreement.

In Excerpt 2, we can see how both of the children are given the opportunity to place their words where they think they should go; they are using the separate spaces to express their agreement and disagreement. Moreover, the need to agree fosters discussion and explanation about why words have been placed and how their location relates to their meaning and/or their structure. It is in this way that SCOSS has a direct role in promoting pedagogically useful educational dialogue.

(The children have spent a long time deliberating over where 'skirt' should go and R has finally agreed with L)

R	Are you gonna click on that agree button?
L	Wait wait. I've put skirt with trousers
R	Yeah
L	And I'm putting…I'm keeping those there [uses his cursor to point to words in his top left box] are you?
R	Where?
L	These. [uses his cursor to point to words in his top left box]. What we've got.
R	Yeah

Excerpt 3. Acknowledging separate spaces in the SCOSS paradigm.

L	What about ankle? ('ankle' is currently in top right box)
R	Hey leave that I just put that there! Get out!
L	Laughs, now lets put ankle in here [moves 'ankle' to bottom left]
R	What?! That's…!
R	[moves 'ankle' back to top right]
L	Ankle goes in there [moves 'ankle' back to bottom left]
R	Moves 'ankle' back top right]
R	Whatever
L	[moves 'ankle' back bottom left] Look!

Excerpt 4. Confrontational use of a shared single space in the single user interface.

In Excerpt 2, the children do not actually talk about the spaces per se; they use them without direct verbal reference to them. However, there were a few occasions where children did explicitly refer to their spaces and the pair in Excerpt 2 did so in another stage of the task. Excerpt 3 illustrates this.

In Excerpt 3, R is asking L whether he agrees on the location of 'skirt'. L recaps the situation, and in doing so he explicitly acknowledges three features of the interface:

- firstly that he has his own space in which he can show what he thinks ("**I've** put skirt with trousers"),
- secondly that R can have a different opinion to his own ("I'm keeping those there, **are you**?"), and
- thirdly that he has separate control of his own space ([uses **his cursor** to point to words in **his top left box**]).

In this example, L is acknowledging that R can have a different opinion to his and is double checking that they have finally agreed. In this way, the provision of both separate spaces and separate control have afforded both children the opportunity to: represent what they each think is the correct location for 'skirt' (i.e. disagree); talk about how they could agree; reach agreement; represent agreement, and acknowledge that they are entitled to disagree. Here, separate spaces are not only a tool used to represent agreement and disagreement, but they also play an integral part in the mediation of the collaborative process.

In direct contrast to the above use of separate spaces, children using the single user interface shared a single space and they could undo their partner's work. This often led to unproductive domination and squabbling, as illustrated in Excerpt 4. Here, the children are arguing unproductively over where to place 'ankle'. Each move they make necessarily undoes what their partner has just done and they cannot represent their own opinion without doing this. Their behaviour is confrontational and does not contribute positively to the collaborative process; the children seem to be focusing on moving the word in order to gain ownership of it, rather than explaining *why* they want it in a certain location.

4.2.3. Representation of agreement and disagreement

In the SCOSS paradigm, agreement between children is represented when elements of the task (in this case, the words) turn from white into green when they are placed in the same location by each child. The utility of colour changes (or greenness), in combination with the provision of separate 'we agree' buttons and separate spaces, is demonstrated in Excerpt 2.

Close inspection of Excerpt 2 reveals how the colour changes are embedded within a conversation that focuses initially on disagreement (represented by italics) then moves through a period of negotiation and ends in temporary agreement when the same words turn green (represented as bold text). We can see how colour changes work to mediate the direction of the conversation: in line 10 of Excerpt 2, child R has placed 'deer' in his top left box and child L has not replicated this, so 'deer' is disagreed upon and L asks R for an explanation as to why he has made the placement. In this example, the fact that 'deer' is italicised simultaneously represents the children's disagreement and prompts them to discuss it. It is also interesting that L points to R's top left box (lines 11, 18 and 22); he cannot point to his own because 'deer' is not there. The target of this pointing reinforces the fact that they disagree; 'deer' is in R's top left box but in L's 'word pool'. It is the ecology of separate spaces, separate control and greenness/whiteness that work to mediate this conversation. A lack of separate spaces and greenness/whiteness in the single user interface makes it unlikely that this will occur. Instead, any re-placements of words will essentially override and delete previous ones, making a similar representation of disagreement impossible.

4.2.4. Individual 'we agree' buttons

In Excerpt 1, the children were using a single user interface so there was a single 'we agree' button that was shared between both children. It needed only one click from either child to activate it (as with 'OK' or 'next' buttons in other software). The child who clicked on this single button should (as intended by the designers) be using it to represent joint (we) agreement but it is clear that in Excerpt 1, R has not ensured that his partner agrees with him. Effectively, this excludes L from registering his opinion. This can allow one child to dominate the other, thus enabling them to rush through the activity even if their partner expresses a wish for more time to think about the task. In the SCOSS paradigm, however, the provision of a 'we agree' button for each child provides them both with an opportunity to play a part in the representation of *true* joint agreement. In the last lines of Excerpt 2, we can see how L refrains from clicking on his 'we agree' button, even though his partner has done so. The provision of separate 'we agree' buttons has made it possible for L to rethink and change his mind. This would not have been possible in a single user interface and the task would have proceeded to the next stage without true joint agreement being reached.

In the SCOSS paradigm, we have also found a few instances of children attempting to dominate their partner's 'we agree' button and have categorised these into three different types:

1. Using their own mouse to click on their partner's 'we agree' button to signal that they should click it. This was usually accompanied by impatience and appears to be an (unsuccessful) attempt to dominate.
2. Verbal signalling that their partner should click their 'we agree' button e.g. ''press it!''. This, too, was usually accompanied by impatience and seemed an attempt to dominate.
3. Reaching over and attempting to physically use their partner's mouse to click on their 'we agree' button. This was very rare and usually ineffective in achieving domination.

These behaviours are attempts to thwart a partner's opportunity to contribute to the process of reaching agreement. They are good examples of a way in which the SCOSS paradigm can work to ensure equity of opportunity to contribute to the task because it increases the likelihood that domination attempts will be ineffective.

4.3. Unproductive behaviours

So far, we have focused on behaviours that we hypothesised would occur; Excerpts 1–5 have illustrated the affordances and associated behaviours predicted in Table 1. As stated above, one of the problems encountered when a pair of children shares a single user interface is that of disengagement, and this is exacerbated by the possibility for the task to be completed by one child. The provision of separate spaces in the SCOSS paradigm was designed so as to engage each child with the task and to reduce the effectiveness of domination attempts, which it does achieve. However, this feature can only give the children a maximum *opportunity* to work in this way, it does not guarantee that they will. Some children chose to utilise the properties of the SCOSS paradigm in less constructive ways, and these will be discussed next.

	Left child	Right child
1 2		I know! It's cos umm, we should put those in there [points with cursor]
3 4	[moves 'glasses'] {*'glasses' turn white*}.	
5 6		[moves 'glasses'] **{'glasses' turn green}**
7 8 9	Those two go together [moves 'hood'] {*'hood' turns white*} [moves 'skirt'] {*'skirt' turns white*}	
10 11		[hovers 'hood'] Why eye, glasses and hood?
12 13 14 15	[moves 'trousers'] {*'trousers' turn white*} I'm just putting hood there for the moment	
16 17 18 19 20		[moves 'skirt'] **{'skirt' turns green}** [gives a big sigh] [moves 'hood'] **{'hood' turns green}** [moves 'trousers'] **{'trousers' turn green}**
21 22 23	I'm not sure about them No, hood should go in there [moves 'hood'] {*'hood' turns white*}	
24 25 26		[gives a huge sigh] [moves 'hood'] **{'hood' turns green}**

Excerpt 5. Blind copying (by R) in the SCOSS paradigm.

4.3.1. Blind copying

The most significant departure from collaborative working that we found with the SCOSS paradigm was when one child blindly copied their partner. This can occur for several reasons such as inability to read the words, general disinterest, or lack of the necessary interpersonal skills to deal with a partner who wants to dominate. The copying child was usually bored and frustrated because their partner was not helping them and was racing ahead, whereas the partner was usually frustrated by the copier's slow progress and was reluctant to explain themselves and to help them. These interpersonal problems and poor collaborative skills are features of pairs that the SCOSS paradigm, alone, cannot address. We carried out the lessons on collaboration in an attempt to address these issues but they were not always effective.

Excerpt 5 is taken from a pair of children using the SCOSS paradigm, where L is impatient and is dominating R. The transcript has been visually divided into two columns to be read consecutively from row 1–26, which emphasises how all L's moves result in words turning white (italicised text), whereas R is concerned with copying her in order to turn them all back to green (bold text) (a small amount of extraneous dialogue has been deleted to aid presentation). The correct response to this round was: things you wear that contain double letters/or not; and parts of the body that contain double letters/or not.

In Excerpt 5, R makes a suggestion (row 1) that is ignored by L. Child L then proceeds to move words without any explanation to R and the question that R asks in row 11 is not given a satisfactory answer. As a result, child R's actions are concentrated on copying her partner; R is using the white colour of words to identify which ones her partner has moved and then focuses on copying those movements in order to turn the words green. She is obviously frustrated as indicated by her sighing. In this excerpt, both children fail to discuss their suggestions or moves with each other and R fails to effectively challenge L and prompt satisfactory explanations from her. This is an example of how poor collaborative skills impact on how the properties of the SCOSS paradigm are used. However, there can be occasions where short-term copying is less detrimental. If a child is unsure of where to place a word, they can be persuaded to temporarily 'agree' or to go along with their partner until more words are received and it can be reconsidered later. This does make further immediate discussion unnecessary, which may be regarded as detrimental, but it is a useful short-term strategy to prevent a stalemate or prolonged unproductive interchanges when one child is genuinely unsure. It is very different from the type of blind copying exemplified in Excerpt 5.

4.3.2. Parallel working

A further unexpected behaviour that was surprisingly scarce, given the opportunity for it to occur, was children working in parallel on different parts of the task. It was possible to do this in both interfaces, due to the fact that children had a mouse each and simultaneous access to the task. However, there are important differences in the outcomes of this behaviour across the single interface and SCOSS paradigm. When parallel working occurred in the single user interface, the single representation of the task meant that the children did not need to attend to each other's actions. However, in the SCOSS paradigm, children had to attend to each other's separate actions because they often resulted in disagreement, which had to be resolved. In this way, the SCOSS paradigm brought the children back together to focus on their differences and, in so doing, meant that the results of parallel working were less detrimental to the process of collaboration.

5. Discussion[4]

This study has provided evidence for the potential of the SCOSS paradigm to encourage both children, within a pair, to contribute to a computer-based task. Our analytic comparison between SCOSS and dual control of a single user interface has illustrated that SCOSS has advantages. Separate spaces provide children with the opportunity to think about and express their own opinions and ideas and hence encourage them to begin from a starting point that is meaningful to them. Their own ideas can then be compared to those of their partner. This use of separate spaces gives children the opportunity to be both visually and verbally explicit about whether or not they agree with each other. The children's acknowledgement of their agreement or disagreement, together with a graphical display of it, can be used to resource further exploratory discussion. Excerpt 2 clearly illustrates how the use of separate spaces can work to open up further discussion, in this case about why words have been placed and how their location relates to their meaning and/or their structure. In this way, the process of the children's conversation is mediated by the features of the SCOSS interface and their activity is an "irreducible aggregate of individual (or individuals...) *together with mediational means*" (Wertsch et al., 1993, p. 401). Less able children can learn from exploratory discussions and suggestions from their more able partner, enabling their understanding to progress within their zone of proximal development (Vygotsky, 1978).

We note that disagreement or conflict resolution featured prominently in the children's discussions and argue that this should be viewed as a positive indication that verbal exploration, rationalisation and the exchange of ideas are occurring, all of which are essential features of constructive collaborative interactions. However, agreement was also an important feature, as the provision of a separate space in which to express their own opinion can empower children to base their agreement upon a full understanding of what their partner thinks, rather than being dominated and pushed into uninformed acquiescence. The SCOSS interface therefore can promote "co-ordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Teasley & Roschelle, 1993, p. 235).

Blind copying is an example of when a child, or a pair of children, lack the social and/or domain skills to collaborate effectively. These children often found the domain difficult and some were poor readers and asked their partner to read the words and to explain the task. When a partner was not willing to do this, it resulted in the less able child having no alternative but to copy. This can be described as uninformed co-operation and suggests that SCOSS alone cannot directly mediate the content and/or social dynamics of collaborative conversation. It can, however, positively scaffold the discursive *process* when the children take the opportunity to use its properties to this effect. Previous work carried out by O'Connor (2004) has incorporated discussion prompts into the SCOSS paradigm and found that they were effective in increasing participant engagement and constructive exploratory interactions within parent–child dyads. In the future we would like to use the SCOSS interface to encourage children to reflect upon their collaborative performance (i.e. increase meta-collaborative awareness) by providing them with system-generated feedback. A log file of each child's input can provide information about relative contributions (amount and type), which can be used, for example, to trigger the appearance of screen prompts. A further possibility is for the system to temporarily suspend input to

[4] We are grateful to an anonymous reviewer for suggestions that shaped this discussion.

the dominant child's space and allow an opportunity for the less dominant partner to contribute. In this way, the SCOSS interface can support the development of both domain and collaboration skills. We would also like to explore how it can be used for tasks that do not require eventual agreement; for the representation of different valid opinions.

It is encouraging that the SCOSS interface has potential applications beyond the study context described above. It could be implemented as part of a CSCL environment to support collaboration between remote workers. It could also be used to teach/improve argumentation skills in educational settings, as it allows for the representation of both agreement and disagreement. SCOSS also has potential for use in industrial settings where workers in different locations may collaborate over, for example, interface design features, document production or mind maps. Its wide applicability makes SCOSS an important contribution to research and development.

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