Making Sense of Collaboration: The Challenge of Thinking Together in Global Design Teams

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ABSTRACT
Industry globalization brings with it inevitable changes to traditional organizational structures. The notion of global virtual teams, working together across geographical, cultural and functional borders, is becoming increasingly appealing. This paper presents observations of how a team of designers negotiate shared understanding in the collaborative design of Virtual Pedals for Volvo Car Corporation. Although the team was globally distributed during most of the development process, examples are drawn from collocated design sessions, since this enables careful examination of the multifaceted ways in which collocated designers use a wide variety of artifacts and techniques to create common ground. The findings highlight the situational and interactional characteristics of design collaboration and suggest that the addition of shared ‘objects to think with’ in distributed interactional characteristics of design collaboration and suggest that the addition of shared ‘objects to think with’ in distributed design environments could greatly facilitate global design teams in their collaborative process of ‘thinking together apart’.

Categories and Subject Descriptors
K.4.3 [Computers and Society]: Organizational Impacts – computer-supported cooperative work.

General Terms
Management, Performance, Human Factors

Keywords
Global design teams, distributed product development, collaborative design, common ground, shared understanding.

1. INTRODUCTION
A key need of the globalizing industry is to become more effective in globally distributed product development [24], which means that cost and time should be cut, while still meeting quality demands on an increasingly competitive market. Companies need to increase their level of competition through the use of a wide array of resources, such as production plants, consultants and educators, made accessible from any part of the world. However, while globalization means that costs and risks can be decreased, or shared in the case of collaborative projects [1], it also implies that changes in traditional organizational structures are necessary. Presently, there is a growing interest in creating global virtual teams, in which collaboration proceeds across time zones as well as across geographical, cultural and functional borders [11, 15, 20, 25].

Work in global virtual teams places demands on both physical and virtual environments that support these geographically dispersed groups with regard to collaboration, communication and coordination. With longer distances between people, many of them with different responsibilities and activities within an organization, the members of the organization need to communicate efficiently despite the challenges that come with collaborating in a geographically distributed work environment. The diversity of such global virtual teams presents a problematic situation where “different participants within different object worlds with different competencies, responsibilities and interests speak different languages” [7].

A crucial concern for distributed design teams is to successfully deal with the process of reaching a shared understanding of the domain, the requirements, the object of work, the design process itself and the roles and commitments of team members [41]. Design is, according to Bucciarelli [6, p.187], “as much a matter of getting different people to share a common perspective, to agree on the most significant issues, and to shape consensus on what must be done next, as it is a matter of concept formation, evaluation of alternatives, costing and sizing”.

This paper presents an observational study of a collaborative design project, where members of a global design team, representing different object worlds [7], were working together to design Virtual Pedals for Volvo Car Corporation, Sweden. Although the majority of work was carried out in geographical separation, this paper draws from examples of their collocated design sessions in order to show how the team was ‘thinking together’, as opposed to the passive transmission and reception of information that was characteristic of their distributed design sessions.

The paper does not approach the concepts of shared understanding, common ground and consensus as products of collaboration; it deals, instead, with the multifaceted process of sense making that designers go through while negotiating shared understanding and the implications this could have for the design of virtual and physical environments that adequately support the process of ‘thinking together apart’.

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2. MAKING SENSE OF COLLABORATION

Design collaboration is framed by the social world, and it is therefore impossible to independently interpret the nature of design specifications and artifact descriptions without understanding the social situation in which they were created [5]. Since design involves communication and interaction between individuals and groups in complex social settings, the social character of design activity is not separated from the technical results. Rather, it is continuously present in the meetings, discussions, arguments, debates and interpretations that make up the intricate weave that is design. As Minneman puts it, design could be seen as a “social construction of a technical reality” [27, p.63].

The process of collaborative sense making is critical to successful design, and it also points to the importance of preserving ambiguity, providing team members with “the freedom to manoeuvre independently within object worlds and providing room for the recasting of meaning in the negotiations with others” [8, p.178].

With reference to design as being a social activity, successful collaboration requires the establishment of a shared understanding, or common ground, between team members. Clark and Brennan [9] use the term grounding to describe the process of making sure that what is communicated is also correctly understood. They further state that “all collective actions are built on common ground and its accumulation” [9, p.222], which emphasizes that common ground is continually built and rebuilt through the moment-to-moment interactions of team members. Such interactions can be found in many different forms, and they all impact the collaborative design process in one way or another. For example, Short et al. [37] describe aspects of visual communication that influence social interaction: “In normal face-to-face interaction, the participants exchange in addition to the verbal material, a range of non-verbal cues such as facial expression, direction of gaze, posture, dress and physical distance” [37, p.153].

Making sense of design collaboration means that common ground must be achieved with respect to the relevance and meaning of the information brought forward during collaborative design activities [19].

2.1 VOCABULARIES OF DESIGN

In a study of industrial designers making concept design sketches, Pan et al. [31] found that the designers used verbal language to describe the form of design in very individual ways; language that was not clear, consistent or commonly understood by others. The authors state that designers have a “creative vocabulary, which has rich meanings in design communication” [31]. In the context of global collaboration between diverse work groups the notion of a common vocabulary of design is very appealing. According to Hill [19], the success of design teams relies heavily on the ability of participants to “negotiate different design perspectives and specialties”, and “similarities in voice” are of particular importance when team members come from different disciplines and backgrounds.

However, the idea of defining a common vocabulary of design seems to be more or less Utopian. Bucciarelli [7] notes that even though participants in design may share a common language, such as English, this language can be used in such specific ways that, in reality, it seems like a participant is speaking a different language: “Not different in the sense that for you, as a foreigner, a translation would make meanings clear...but different in that the concepts and ideas and relationships among the things of an object world require new learning, like the learning of a foreign language”.

Essentially, this means that design teams, global ones in particular, not only face the challenge of negotiating shared understanding between, for example, people with varying language proficiency, but they also face the challenge of negotiating understanding between people coming from completely different object worlds – depending on, for example, cultural and educational backgrounds and professional disciplines.

I find negotiation to be a rather suitable term to describe the communication between members of a design team, largely because it implies that participants are actively shaping the context and content of the situation rather than passively transmitting and receiving information with a well-defined meaning within a well-defined setting. Sense making is a collaborative process, and as Bucciarelli [7] observes there is an inherent ambiguity of translations between object worlds, giving designers the all but trivial task of “frequently bringing the results of their object world efforts, which no doubt will conflict, into coherence if design is to proceed – and they must do this without a shared proper language”.

2.1.1 Storytelling

One of the ways in which designers negotiate understanding is by telling stories. Storytelling enables them to explain, more specifically than through more formal accounts of work, what they actually do, as opposed to what they should do if following normative models of design [26]. Even if the stories do not directly solve a problem, they can help in building a shared vocabulary for talking about the design, creating “a new language capable of describing aspects of the evolving design” [26].

In a way, stories can enable designers from different object worlds to reach shared understanding through a commonly agreed story, to which they can refer, whether they choose to agree or not on specific subject matters. Stories are concrete examples that people from very different backgrounds can relate to, and since the informality of stories prevents us from taking them too seriously, they serve as a commonly available resource of knowledge, open for interpretation and questioning by all participants [12]. As observed in Orr’s [30] study of service technicians, stories can serve the purpose of preserving and circulating experience within a community and such narratives can provide a common frame of reference in problem solving activities.

Another important feature of stories is that they can become vehicles for thought in the sense that while using them we not only explain things to others, we also explain things to ourselves [28].

2.1.2 Indexical Expressions

While stories can be useful when making sense of design collaboration, there are other ways in which designers make use of representations, which means that they are working with marks or symbols that represent something else and then do their reasoning
through the use of those marks [28]. Similar to the concept of storytelling, such representations provide designers with concrete examples that better match their thinking about the design task at hand; basically, they are using the available tools that best support negotiation between team members at a particular moment.

In relation to the idea of a common vocabulary of design, it is important to acknowledge that some parts of such a vocabulary cannot, under any circumstance, be strictly defined. Designers, as other human beings, often use indexical expressions when communicating and such utterances “cannot straightforwardly be repeated or reused outside the context in which they originated, without changing their meaning” [23]. For example, the meaning of words such as ‘here/there’, ‘this/that’, ‘him/her’ or ‘now/then’ cannot be adequately understood without knowledge about the circumstances of the particular situation in which these utterances were made.

2.2 Objects of Design

Harrison and Minneman [18] observed that objects are integral to design communications since they form part of the pool of representations that are available to designers. These objects can be practically anything: for example a pen, a chair, a sketch, or a simple sheet of paper. In concept design, such objects are essential to collaboration because there is no ‘shared’ object of design that early on in the product development process [42]. Thus, a shared object must be constructed through collaboration in order to enable discussions around design options and tentative ideas.

An important attribute of such coordinative artifacts [35] is that they are publicly accessible, which means that they can be observed, inspected and made sense of by all participants of a team [35]. Thus, common ground can be negotiated through the use of a physical object that is equally accessible, rather than trying to find common ground through verbal communication alone.

The actual properties of objects being used by design teams are not necessarily optimal or entirely suitable for supporting design thinking [3]. In her study of design students using physical objects to prototype designs, Breteron [3] found that it is probably not possible to specify in advance what kind of object that would be suitable or desirable in a particular design situation: “The hardware was simply conveniently available and had some attribute that meant students found it helpful to gesture and think with” [3].

Donald Schön’s observations of designers reveal that when they are drawing sketches they are actually engaging in a “conversation with the materials of the situation” [36, p.79], in the sense that they first draw something, then they interpret their sketch, and then they continue to draw. Similarly, Gedenryd [16] observes that the process of drawing makes the designer think and generate new ideas in “stepwise reasoning-by-drawing”. It is also interesting to note that ‘rough’ prototypes that are created quickly are often preferable to more accurate prototypes because they allow for a quick exploration of the design space [16]. In this sense, “prototypes do not have a productive, but an inquiring purpose” [16]. Thus, the way that we understand and use an object is not simply restricted to the object in itself, but it is also closely linked to the ways in which the object is presented. Such a presentation often includes, in addition to verbal descriptions, elements of pointing, showing, and highlighting [17]. Tang [39] further acknowledges the importance of non-verbal cues in design collaboration: “Gestures, the process of making drawings, concurrent access to the drawing space, fluent intermixing of drawing space actions, and the ability to associate the marks with who is making them, all contribute to maintaining effective communication and collaboration” [39, p.258].

2.2.1 Conversational Props

The inquiring purpose of using objects to promote understanding essentially means that designers look for physical artifacts that can help them both in their own thought process and in the process of communicating ideas to other members of the design team. Such objects are sometimes referred to as conversational props [4] that add an element of realism to a conversation.

2.2.2 Boundary Objects

Artifacts can also serve as mediators between different individuals or groups in that they “become the terrain on which conflicts and collaboration occur” [32]. When team members are from different object worlds, with different interests and goals, design artifacts can be seen and used as boundary objects [38] that are useful representations for all members of a diverse group, but that still could have a more specialized meaning to each member. Boundary objects “have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation” [38, p.393].

According to Bucciarelli [7], boundary objects or shared artifacts are essential even in situations where participants are from the same object worlds, since the analytic nature of proper language “hardly allows for the kind of experimentation and innovative thinking that designing requires”.

2.3 Places of Design

The context of work also includes the rooms and places that designers occupy while designing. For example, team rooms or conference rooms are most likely equipped with ‘standard’ conversational props, such as whiteboards, flip charts and overhead projectors [34]. In situations where design teams occupy a room over an extended period of time, the writings and sketches on whiteboards and flip charts can serve as visible permanent records [40] of group activity and decisions. Also, project plans, agendas and ‘to-do’ lists are often posted in ways that make them visible and easily accessible to anyone at a glance [40].

Places can be seen as a collection of conversational props, and the spatial arrangement of these props is often very important. For example, Olson [29] observed that artifacts were often put up in the order in which they were produced, which in turn meant that participants “knew where to look for something because they knew when it was produced” [29]. Similarly, Kirsh [22] noted that places offer a lot of mechanisms that help individuals and groups to coordinate work, distribute tasks and manage the flow of information so that they are able, for example, to “recall why they left papers out, why folders are open, why there are certain marks on the whiteboards” [22].
In the collaborative shaping of common ground, it is useful to be able to focus attention on a shared object, and point to various places on it [29], but rather than the mere characteristics of a particular object, it is often the whole context of a room that enables such collaboration. For example, people can draw in the air to explain an idea to others, and they can later on refer to ‘that idea’ by pointing to the spot in the air where the first person had ‘drawn the idea’ [29]. One of the foundations of the ‘perfect brainstorm’, according to the award-winning design firm IDEO, is that ‘the space remembers’ [21, p.59]. Spatial memory is powerful, and when idea sketches are spread all over a room “spatial memory will help people recapture the mind-set they had when the idea first emerged” [21, p.59] as they return to the spot on the wall where that idea was captured. IDEO is also famous for letting team members shape their own creative office spaces that are evolving, elastic, inspiring and even amusing [21].

3. CASE STUDY

3.1 Virtual Pedals

The case study to which this paper refers was carried out within the Distributed Team Innovation (DTI) framework, a collaborative project between the Polhem Laboratory at Luleå University of Technology, Sweden, and the Center for Design Research at Stanford University, USA. The overall aim of the DTI framework is to decrease the negative impact of geographic distance on product development efforts and to further enhance current advantages of worldwide, multidisciplinary collaboration [24].

As part of the DTI framework, a global product development project was carried out by a distributed design team consisting of four students from the ME310 course at Stanford and four students from the SIRIUS course at Luleå. The goal of the project was to design Virtual Pedals for Volvo Car Corporation, taking into account the fact that the need for mechanical connections between pedals and actuators has disappeared with the introduction of drive-by-wire (electronically controlled systems) technology in the automotive industry. Such a pedal system could help eliminate foot injuries caused by mechanical pedals in the majority of frontal collisions, but it could also allow for position and feel adjustability, cost reduction and safer driver positioning.

The design space was very wide in this particular project, and the only initial limitation was that the accelerator and brake should be foot controlled due to the force of driving habit. The Virtual Pedals project started in October 2001 and concluded in June 2002 with a fully working prototype of an innovative foot interface that was installed in a Volvo S80 car thus enabling actual test-driving. Another prototype, complete with adjustability, was installed in a test rig for future investigation. A patent is pending.

The observations presented in this paper originate from a total of three weeks of collocated work (two weeks at Stanford in mid-January 2002 and one week at Luleå in late-March 2002). On both occasions, the design team was working with concept design, although the scope differed somewhat on these occasions. The work in January involved a lot of brainstorming and idea generating (divergent thinking), while the focus of the March sessions was to reach consensus on the final concept (convergent thinking).

3.2 Methods

The observations of both collocated and distributed collaboration were carried out during six months of the seven-month student project. The goal was to study communication and interaction as it played out in actual design activities, as opposed to studying designers carrying out specific design tasks in ‘controlled’ settings. Drawing from the concept of ethnomethodology [10], it seemed important to try to understand design collaboration in the context in which it occurs.

The study was performed using ethnographic methods such as observations, field notes and videotaping. [2] Apart from the intentions to strive for an ‘inside perspective’, ethnographic methods were also suitable since the structure of groups and communication is continually changing. As Gale [14] notes, “the effects of technology on a group may take weeks, months, or even years before becoming apparent. These sorts of effects cannot be fully explored in a one-hour experiment”. This is also one of the reasons why the team should be studied during both the divergent and the convergent phase of concept design.

4. FINDINGS

This section presents four fieldwork transcripts of design team collaboration within the Virtual Pedals project. These transcripts have been chosen as examples because they are representative of the activities that were observed during the course of the study.

The main idea behind presenting and discussing these representations of collaboration is to point to how subtly, fluently and effortlessly designers negotiate common ground in collocated collaboration. In order to reach a shared understanding about concepts of ‘acceleration’, ‘braking’, ‘foot injuries’ and ‘gas travel’, they use a wide variety of tools for thought, including verbal language, physical prototypes, sketches, gestures and even their own bodies.

4.1 Making Sense of ‘Acceleration’

The following transcript concerns a discussion that the design team had while the Luleå students visited Stanford in the beginning of January 2002. They are in the brainstorming phase of the concept design stage, and the team is trying to create consensus about how one of their concept ideas ‘really’ works in terms of acceleration. Figure 1 shows a snapshot taken as one of the students (SS) is describing the potential problem of accidentally accelerating and braking at the same time.

Simplified transcript #1: ‘Acceleration’

SS: “It’s not with your heel off the ground [lifting right leg] though, he’s right [pointing at MP], it’s with your whole foot [lifting right leg again, holding it in the air]...even though you’re in this position, it’s your whole foot sitting there.”

JW: “Your whole foot’s on the pad, right? [lifting right leg, pointing at the foot]”

SS: “Your whole foot’s on the pad...[nodding]”

JW: “[pointing at his right foot, gesturing]...when you slide up, you’re still touching it but you don’t...you’re suspending your foot...except...
there’s a little friction [gesturing] keeping it there, but basically you’re just suspending your foot.

SS: “I think that if you do that [right leg still in the air], and you have pushing [pushing motion with leg] for the brake also at the same time, that’s going to be difficult, because as you slide up [sliding motion with leg] you’re going to want to push in [pushing motion with leg] to hold it in place…”

SS: “…and in an accident you can have this kind of…belt stretcher [gesturing to demonstrate a seat belt] attached to it so it…pulls it back [gesturing]…”

MP: “Well, it does not have to move while you’re breaking [taking the swivel chair], ’cause you know, you can be braking [pushing down on seat with right hand] by doing this…this could be actuating the brake [pushing with both hands]…”

In this situation, SS is extensively using his right leg in order to imitate both the general driving position and the position of the foot in relation to the pedal. JW continues using the leg as an appropriate representation as he confirms that “the whole foot’s on the pad” by pointing to his own foot. Interestingly, what then follows is that JW is continuing his thought process while pointing to his own foot and making a gesture to imitate ‘friction’. This is similar to the “stepwise reasoning-by-drawing” observed by Gedenryd [16] in that JW actually seems to be making up his mind about the concept at the same time as he is in the process of visualizing this to the other team members. SS can then rather seamlessly connect to JW’s story and go further into the potential problems of simultaneous acceleration and braking.

Apart from serving the purpose of emphasizing and making sure that what is said is also being understood by all participants, the use of body language could also be a way for the designers to ‘get a feel’ for the use situation that they are designing for. In reality, driving a car involves many different parts of the body, and when discussing driving it is only natural to involve the human body as one of the many representations that could be used to enhance the understanding of what it is like to drive a car with Virtual Pedals.

Note, too, that in Figure 1 the walls are covered with concept design sketches, the table is covered with prototypes and all kinds of ‘possibly useful’ objects, while prototypes of ‘paper bikes’ are hanging from the ceiling as a source of inspiration and innovation.

4.2 Making Sense of ‘Braking’

In the situation from which the following transcript is taken, the team is in the same brainstorming phase as above, but they are now trying to achieve a shared understanding of how the brake should be actuated in the concept idea that they are currently discussing. Figure 2 shows how one of the students (HA) is using a chair to convey his ideas to the other team members.

In this sequence a regular swivel chair has been adopted as an appropriate object to represent the car pedals. Looking only to what is being said, it seems rather strange to “measure the force” in the legs of a chair, but in the above context there is no question about what HA is referring to. HA is also performing a ‘seat-belt gesture’, maybe because he is not certain that he is using the right English term (since he is Swedish), or because he is unsure about whether the other participants will follow his train of thought (How does a ‘belt stretcher’ relate to car pedals?).
MP is using another part of the chair to demonstrate how he thinks about the braking function. The flat and soft surface of the seat seems to match the properties that MP was searching for in order to make a suitable connection between the conversational prop and the concept of car pedals.

The chair serves as a boundary object in the sense that it is used differently, for different purposes, by two members of the same design team. HA is using the legs of the chair to refer to the braking mechanism, while MP is using the seat of the chair because the properties, or affordances, of the seat suited his thinking about a ‘non-moving’ pedal.

Basically, they used an object that was conveniently available and appropriate for the task. Common to both HA’s and MP’s behavior was that they ‘monitored’ the reactions of the other participants in order to make sure that their use of the conversational prop was understandable also to the others.

4.3 Making Sense of ‘Foot Injuries’

The transcript below relates to a situation in the phase of concept design where the team was trying to converge into a final concept that would be installed in a vehicle. The session was held during the Stanford team’s visit to Luleå in late-March 2002, and although the team was in the latter stages of concept design, there were still important design choices to be made. In this situation the discussion concerned safety issues. In Figure 3, one of the students (JP) is using a notepad and his right hand to visualize a foot ‘slamming’ into the pedals in the event of a collision.

The above transcript shows an example of a highly multimodal activity, where the designers make use of a wide variety of representations in order to negotiate shared understanding. Hand gestures are used to imitate ‘bending’ and ‘flexing’ of the foot, as well as comparing ‘dynamic’ versus ‘static’ driving. Also, JP is using a notepad that represents the pedal in his story, or scenario, of what happens in a collision.

In the end of the transcript, SS is using the whiteboard to clarify what the ‘issue’ is, and it is interesting to imagine what it would be like to try to achieve shared understanding based only on his speech, without the ability to connect the indexical references (‘here’/’like that’) he is making to his sketches and gestures.

4.4 Making Sense of ‘Gas Travel’

The last transcript is also from the sessions held in Luleå in late-March 2002. One of the students (HA) has brought forward a possible improvement of one of their earlier concepts, and he is trying to explain how the new design idea relates to the previous version with regard to the amount of ‘gas travel’ that is needed for the gas pedal. Figure 3 shows HA using a prototype as an aid to discussion, while SS is using the whiteboard to further clarify that they understand each other.

Simplified transcript #3: ‘Foot injuries’

SS: “...second topic is...you know...is the...having your foot flat [gesturing] on the pedal versus off [gesturing] of it...and having your heel on the ground...so there’s the potential of bending [gesturing]...and injuring yourself like that...”

JW: “...yeah, and I think, if your foot’s on [gesturing] the pedal...it’s just...I think that what we found is that if your foot is on [gesturing] the pedal it’s better for dynamic driving...and if your...you can have your heel off [gesturing] and stuck, it’s better for static.”

JP: “...is this the issue with having a flat surface that you...that you’re having your foot flat on the pedal [using notepad as pedal, right hand as foot], is it then...in an accident, if your foot’s a little bit away [puts hand away from notepad], it’s going to slam in [slamming hand into notepad]...whereas if you have an accident your foot’s already flush with the pedal [hand is kept flush with notepad]...it doesn’t go anywhere, it just presses in [pressing hand into the notepad]...is that, was that the issue we’re talking about?”

SS: “No, the issue we are talking about is [stepping up to the whiteboard, taking a whiteboard marker]...if your [drawing]... foot is ... here [pointing/drawing] and here [pointing/drawing]...and like, let’s say the pedal’s over here [pointing/drawing]...and your toe’s here [pointing] and your heel’s here [pointing]...in an accident there’s a potential to flex [gesturing] like that...”

Simplified transcript #4: ‘Gas travel’

JW: “So, in this [pointing at whiteboard] one you’re not actually moving your foot?”
HA: “Yeah, you can make it move but using [pointing at whiteboard]…instead of this aluminium here [picking up prototype] you use some metal that [pointing at prototype] actually works as a spring, and you measure the…then you got the motion this [gesturing] way…”

SS: “It’s equivalent to having like a compression spring underneath here [adding to a sketch on the whiteboard], right?”

HA: “Yeah, but a compression spring is…you’ve got a lot of travel [estimating using thumb and index finger], you don’t need that much travel [once again using finger measure]…”

JP: “We do need some travel…”

HA: “I think we agreed like that … we definitely want like a couple of inches of travel for the gas, is that right?”

SS: “Yeah, I think so…”

HA: “I think just to control the gas you need maybe like this [finger measure]. I think in a car it’s not much more than this [finger measure]…”

SS: “That’s about an inch and a half…”

Figure 4. Making sense of ‘gas travel’.

In the situation above, the team is using a variety of objects to discuss around. The discussion starts from one of their earlier concepts, to which HA offers a possible improvement. Since common ground already has been reached about that particular concept, it is a suitable reference for further elaboration. JW starts by bringing up a fundamental difference between the two concepts – the amount of foot movement required to operate the gas pedal. HA points at the whiteboard to establish an explicit reference between the two different concepts, but in order to more clearly describe his thoughts about ‘gas travel’ he picks up one of the physical prototypes developed earlier in the project. He is using the prototype to illustrate both the actual position of the ‘spring material’ and the direction of motion when actuating the gas pedal with the foot. However, SS finds it more useful to add to an existing concept sketch on the whiteboard, possibly to point out that HA’s concept is not so much a completely original concept as it is a potential evolution of an existing concept.

Ultimately, the discussion above is a way of getting a shared understanding of the amount of ‘gas travel’ needed rather than a rational process of selecting the actual machine part (spring/metal) that will deliver the expected behaviour. Even though the team benefited from the use of selection and rating methods, such as the Pugh concept selection method [33], there was much work involved in the building of a shared understanding about what ‘ease of position adjustability’, ‘ease of control’ and ‘high level of comfort’ means in the context of this particular product development project.

The different criteria that were weighted in the selection matrices have no distinct meaning that enables a ‘rational’ and ‘valid’ selection process regardless of context. The aspects of ‘acceleration’, ‘braking’, ‘foot injuries’ and ‘gas travel’ described above are just some examples of how the design of an object is influenced by and through the multifaceted communication and collaborative sense making that take place between members of a design team. In this sense, the approximate finger measure provided by HA in the final transcript may very well be as important to the outcome as many of the parameters, forces and angles that have been carefully calculated and written down in specifications and other types of formal documentation.

5. DISCUSSION AND CONCLUSIONS

The findings from the observational study described in this paper serve two main purposes. First, they confirm previous findings that highlight the importance of viewing design as a social activity rather than as merely a systematic process of going from a set of initial requirements to an ‘optimal’ solution – using guidelines that are general to every type of design activity. Second, the findings imply the need to re-think the ways in which we support global design teams. Although advances in broadband videoconferencing systems show promising results of sending and receiving ‘hi-fidelity’ audio and video across continents, there is still an immense potential for improvement when it comes to designing virtual and physical places where global design teams can collaborate in more ‘natural’ ways than existing distributed environments allow.

When making sense of Virtual Pedals, the members of the design team made use of just about anything that could help them communicate their ideas. Where verbal language was not enough, they used gestures, chairs, sketches, prototypes and all possible types of objects to visualize and describe what they wanted to ‘say’. The negotiation of meaning also involved the telling of stories and an extensive use of indexical representations, which implied that knowledge of the context of work was extremely important for common ground to be achieved.

The findings suggest that the essence of true collaboration is that team members are actually ‘thinking together’ rather than only
exchanging information and opinions. Meaning is collaboratively constructed in the negotiations, discussions and arguments that designers continuously have in their everyday work, and the observations presented in this paper indicate that current technical systems for distributed design are still lacking support for many of the activities that ‘thinking together apart’ involves.

Given that “physical objects live in one place” [13] it is appealing to be able to provide global design teams with collaborative environments that allow them, for example, to successfully negotiate shared understanding of how it ‘feels’ to drive with Virtual Pedals, or to shape consensus about concepts of ‘comfort’ and ‘ease of use’, when only one of the sites has access to a physical prototype.

While shared electronic media is useful and many times sufficient for distributed design, the addition of shared ‘objects to think with’ is an interesting approach to the further advancement of global design collaboration.

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