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Abstract

Collaboration between disciplines is necessary when research questions cannot be answered within a single discipline. Joining of forces can produce results that neither discipline could provide alone. Here we exemplify collaboration between a ceramic craft researcher and three neuroscientists working in the field of human brain imaging. In our case study of clay throwing, the researcher–practitioner's eye gaze, muscular activity and hand acceleration were recorded online, synchronized with video and thermal-camera recordings. We describe the experimental setting and discuss, besides the possible future interests *in this kind of research, also the different levels of collaborative work between disciplines. We found that the monitoring methods worked well in the naturalistic setting in a ceramic studio, providing some new perspectives into the craft practice. For neuroscientists, clay throwing – involving accurate sensorimotor hand control, haptics and eye–hand coordination – provides an attractive setup to extend previous neuroscientific and behavioural findings in strictly controlled laboratory experiments into naturalistic situations. The applied monitoring devices might allow practitioner–researchers in crafts to become aware of unconscious steps in the making process. The applied methods could also help to accumulate general craft-making knowledge and build related theory.*

interdisciplinary research
convergence research

Introduction

In a recent craft conference (*Biennial International Conference for the Craft Sciences*; BICCS2021 – Craft in Action, Mariestad, Sweden; https://biccs.dh.gu.se/2021) we presented a joint keynote 'Hands in clay: Craft sciences meet neuroscience'. The keynote contained a dialogue between the authors, a ceramic craft researcher–practitioner and three neuroscientists working in the field of systems neuroscience and human brain imaging. The keynote also included a demo recording in which the researcher–practitioner was throwing a clay pot while wearing action-monitoring devices for eye gaze, muscle contraction and hand acceleration. The craft researcher's actions were further monitored with a standard video and a thermal camera, as shown in Figure 1.

This collaboration elicited considerable doubts among colleagues of both parties already in the planning phase. The craft colleagues questioned the benefits of this procedure for craft profession and craft research, whereas the neuroscientists' colleagues felt that making physiological measurements in a ceramics studio necessarily produces messy data that cannot be controlled well enough and therefore not properly interpreted. So why did we join forces to monitor the clay-throwing process so closely? In the following we will explain our interdisciplinary approach and the motivation for it especially in the craft context, since the keynote was presented in a craft conference and because this article will be published in a Special Issue of *Craft Research Journal*.

How this collaboration started

Our initial goal, starting from the neuroscientists' interests, was to develop naturalistic experimental settings for studying hand control and eye–hand coordination. Such a methodological development is important because the results of laboratory experiments with carefully controlled stimuli and setups cannot be generalized to real-life situations where humans live and act. In this process, one of the key aspects is to be sure about the reliability of the applied methods. In an earlier pilot experiment, one of the neuroscientists, who is also a hobby ceramist, was throwing small clay pots in

Figure 1: The setting of the current study. The craft researcher–practitioner wears action monitoring equipment while throwing clay. This screenshot is from the actual video, and the inserts show simultaneous views of the thermal camera (upper left corner) and eye-tracking scene camera (upper right corner). Electromyography electrodes and wires are visible on both forearms, and accelerometers are seen on the fingers. In addition, the rotation velocity of the throwing wheel was monitored simultaneously (not shown in the figure). The images are from a video was taken by Iikkamatti Hauru at the Aalto Studios: https://studios.aalto.fi/. Accessed 26 July 2022.

a setup developed for that specific task (Hari et al. n.d.). The same setup was applied in the current study, including measurements of eye gaze, arm-muscle activity, hand acceleration and video, now we added also wheel speed measurements and thermal-camera recordings.

When the initial neuroscientist team invited the craft researcher to discuss an article on the pilot recordings, a vivid conversation about potential mutual interests started. The craft researcher had already earlier studied clay throwing processes from an embodied-cognition perspective in her doctoral thesis, as part of the 'Handling Mind' research project (Handling Mind Research Project n.d.) that involved researchers from neuroscience, psychology and creative arts. The experienced craft researcher soon joined the current neuroscientist team in a renewed and iterated version of the experimental setup, in which she was throwing a large clay pot so that a longer epoch of data could be collected. A video of the experiment, the applied methods and a dialog between the researchers is available from the conference keynote presentation (Hari et al. 2021).

In the keynote, we discussed the nature and feasibility of collaboration between such distant disciplines as creative practice and neuroscience. When people from different disciplines collaborate, they need to get familiar with others' world-views and step outside their own comfort zone to try to understand other researchers (Kahane 2017; Groth et al. 2020). Even when it comes to commonly used words such as 'knowledge' and 'science', people from different disciplines may have different meanings for them.

Neuroscience is a very multidisciplinary branch of science, scrutinizing the structure and function of the whole nervous system from microlevel (such as neurons, their connections and signalling) to the functioning of the whole brain and behaviour. As is well known, the classical scientific approaches attempt to find new knowledge by making hypotheses based on earlier knowledge, collecting data and then finding out whether the data would lead to rejection of the hypothesis and thereby to development of new theories and models. Scientific approaches can also be based on the 'data mining' where careful analysis of large amounts of data, (big data), may lead to unravelling of new dependencies and principles. Moreover, new instrumentation (such as microscopes and telescopes) and techniques have typically led to new scientific discoveries, as have done many serendipitous inventions and insights. Scientific results are convincing if they can be replicated using other samples of data by the same or another research team using methods that are made available to the whole scientific community.

In the discipline name Craft sciences, the words craft and science may appear contradictory. However, we must note that the word 'science' is used differently in different languages: In English, 'science' is more closely related to the so-called hard sciences, such as physics, chemistry, biology or neuroscience, whereas the Swedish word 'vetenskap' as well as the German word 'Wissenschaft' are more open to different interpretations of knowledge and knowing. Moreover, 'vetenskap' and 'Wissenschaft' include humanistic and qualitative forms of knowledge, as well as personal, practice-related and intrinsic forms of knowing that are important in craft practice and craft research.

In this study, an example of a typical craft practice, throwing clay on a potter's wheel, allowed us to test different monitoring methods and to discuss different dimensions that are included in such an activity. While entering such interdisciplinary research setting, we can start looking for mutual interests and gain knowledge and understandings of phenomena that would otherwise be situated beyond the disciplinary borders and therefore remain inaccessible to us. However, as our proof-of concept study includes only a single crafts person, we cannot go too far in the interpretation of the measurement results. We rather hope to open up new avenues and discussions on the type of questions that could be addressed in future studies in similar settings.

Clay throwing provides an attractive naturalistic task in which neuroscientific and behavioural findings on sensorimotor hand control, haptics and eye–hand coordination can be extended to real-life conditions beyond strictly controlled laboratory settings. The neuroscience team had already abundant experience of other types of naturalistic experimental setups that paved the interest for this type of study; the previous studies were related to, e.g., action observation (Hari et al. 1998), movie viewing (Lankinen et al. 2018) and listening to continuous speech (Koskinen et al. 2020).

Eye–hand coordination, which is important in any craft and in learning manual skills, was thus of mutual interest, as was the haptic dimension of the making process. While eye–hand coordination is crucial in any craft practice, clay manipulation or even clay throwing can be also done solely by haptic guidance, with eyes closed. Such purely haptics-based clay throwing has been successfully taught to for example deaf–blind persons (Groth et al. 2013). However, potters tend to make shorter pots when deprived of their vision (Ziat et al. 2018).

When clay throwing is taught, it can be beneficial for the apprentices to close their eyes, and in the absence of visual input to concentrate on the feeling of the material in their hands. Masters can press the apprentices' hands to show in a haptic way how to manipulate the clay, how to move the fingers and how hard to press the hands on the clay. Sometimes this is the only – and most efficient – way to communicate to students how much force they will need to move the clay in the wanted direction. Potters have been considered as a 'tactually experienced population', with superior haptic abilities and accuracy compared with university students (Power and Graham 1976). Such heightened tactual experience is thought to be a general trait in persons who are using their hands often for making sensory evaluations (Nicholas 2010).

Some physiological monitoring of manual manipulation of clay has been conducted earlier; for example, heart-rate variability measures indicated that clay forming required more effort than the mentally relaxing drawing (Rankanen et al. 2022). However, the present setting (and our preliminary study, Hari et al. n.d.) is, according to our understanding, the first-ever combining this kind of monitoring and clay throwing. In the following, before presenting the experimental setup, we will explain some basic features of clay throwing on a potter's wheel.

Clay throwing

Clay throwing represents craft skills that contain abundant experiential knowledge in material manipulation. The expertise is traditionally transferred nonverbally by observation and imitation in master–apprentice relationships (Sennett 2009; O'Connor 2007). Clay throwing involves smooth coordination between sensory (tactile, visual and auditory) input and motor output. Thus, the potter is all the time closely connected to the environment via an 'action–perception loop' (see Hari and Kujala 2009) that connects action (motor output) with its sensory consequences and adjusts the motor action according to differences between the predicted and realized sensory feedback.

Such interaction between the craftsperson and the environment and materials can also be discussed in the framework of affordance theory (Gibson 1983, 1979). Affordances are opportunities or constraints that either afford or hinder certain actions in the process of doing; the acting person can either select or deselect these clues of possible actions (e.g., you may see a chair but do not need to sit on it). Constraints are present in the environment, the organism (person) or in the tasks in the form of material/technique, the makers' own body/skills and task goals/time, leading the practitioners to coordinate their tasks according to what is feasible in that situation (Newell 1986).

Successful clay throwing on a potter's wheel includes many tasks that build on each other. When starting to throw a basic clay cylinder, one first needs to properly centre the clay in the middle of the throwing wheel to advance to the next stages, such as making a hole in the middle and rising the clay walls. In this type of chain of operations (Leroi-Gourhan 1993; Nørgaard 2018: 247), each operation needs to be successfully managed before one can progress to the next stage, leaving little space for creative choices. Task constraints can arise from the properties of different kinds of clay, the density of the clay at different moments of the process, or the speed of the throwing wheel, or they can depend on the practitioner's skill level. The material constraints and affordances lead to an overlap of evaluation, decision-making, problem-solving and action phases, some of them being predominant at one time (Groth 2015).

To pass all stages without too much risk, the practitioner must plan ahead, 'plant' cues and prepare for future stages along the whole process. Under risky situations, such as when the clay becomes uncentred for some reason, the whole process risks failing. Often such critical incidents (Flanagan 1954) are learning points, and by overcoming them the practitioner gains new knowledge of the process. Actions are selected on the basis of the practitioner's emotions or 'gut feelings' that themselves are based on similar previous experiences, rather than on conscious reflection

(Groth 2015). Such intuitive knowing is built up over longitudinal experience and expertise in similar situations but is seldom visualized or verbalized in any way, even for the practitioners themselves. Wouldn't it be interesting to follow the progression of a craft practice from the beginning to the end to find out whether new information could be learned on the different strategies for navigating in this creative space?

Craft research frequently emphasizes the validity of subjective knowledge (Niedderer and Reilly 2010; Ingold 2013). As craft skills are personal, linked tightly to individual styles and artistic identity, it is difficult to generalize such experiential knowledge (Biggs 2004). However, some general aspects related to a particular technique or material conditions are similar, as are also strategies for managing tasks because of the mechanical constraints of, e.g., clay throwing. Thus, practitioners share views on how to manage certain tasks that might build craft theory if made explicit.

Experimental setting

Figures 1 and 2 show our experimental setting and the monitoring devices while the craft researcher is throwing clay.

The craft researcher's eye gaze was tracked with head-mounted eye-tracking glasses to learn about the site of her attention; the glasses recorded a video from first person perspective and the gaze cursor was overlaid on top of each video frame. The glasses provided gaze-position accuracy around 0.5°. Thermal camera was used to measure infrared radiation from the person throwing clay, as well as from the clay pot itself and the surrounding tub with a sensitivity about 0.04°C. The thermal camera was placed about 1 m from the craft researcher and wheel, so that the hands, face, pot and wheel were visible in the camera view. Surface electromyography (EMG) was recorded from both arms and finger acceleration from both index fingers. Our main aim was to test the functionality of these measures, for example that the wires and electrodes did not restrict the actions of the craft researcher and that the data were clean without artefacts or the signals were strong enough. Accelerometer and EMG recordings provide complementary information about motor actions. The accelerometer outperforms EMG in detecting small vibrations associated with the rotating potter's wheel and hand movement on the clay, whereas EMG is superior in detecting the contraction level of a specific muscle. Accelerometer signals are linear with respect to acceleration, whereas EMG is nonlinear with respect to force applied. The rotation speed of the throwing wheel speed was measured with an in-house-built photoswitch utilizing multifilament fibre-optic cable (see Jousmäki et al. 2007). A white paper with one black stripe was taped on the bottom of the wheel, and the photoswitch was used to monitor the white-to-black changes and thereby the angular velocity of the wheel.

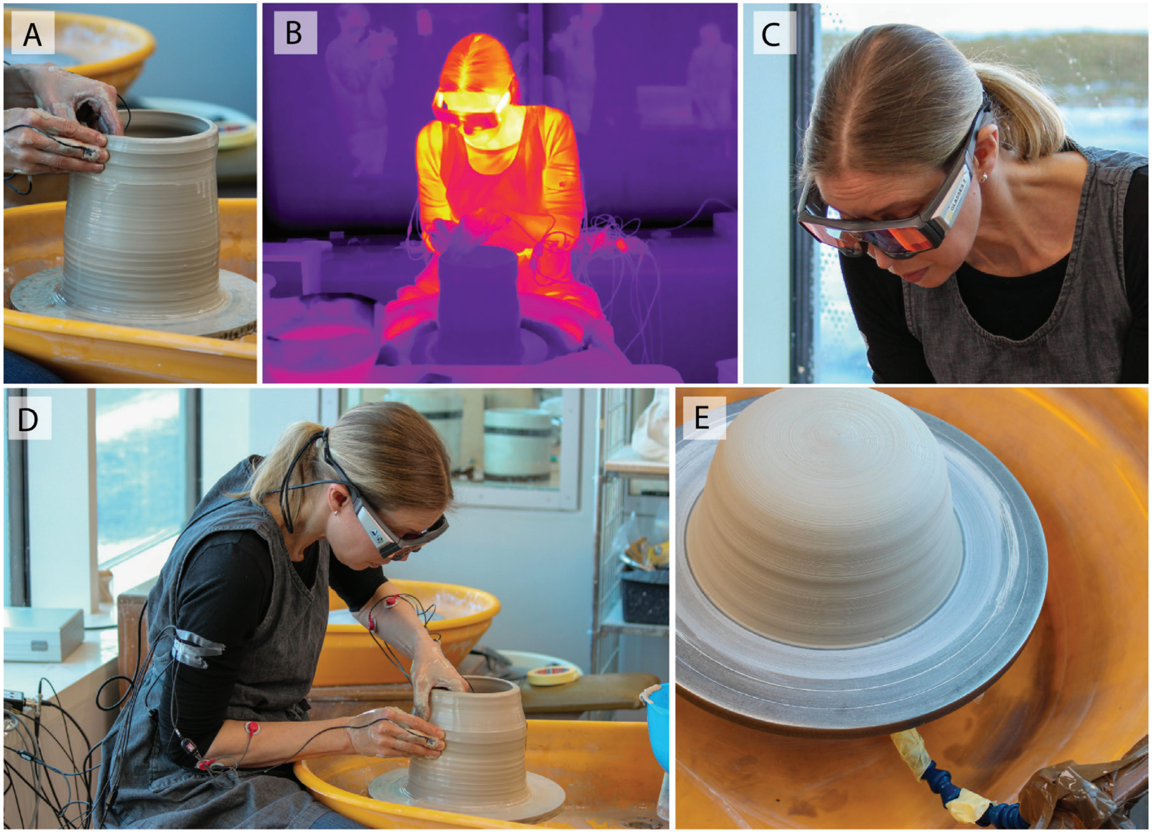

Figure 2: Multiple devices used in our clay throwing task (Panel A). The craft researcher is wearing eye-tracking glasses (SensoMotoric Instruments GmbH, Germany; Panels B–D) that contain an eye camera, infrared light source and head-mounted scene camera. The whole scene was videoed with one static camera and one handheld camera and with a fixed thermal camera (FLIR T620Bx; FLIR Systems Inc., USA) shown in Panel B where the colours indicate temperatures, from about 19°C for the wet clay (dark blue) to about 33°C for the craft researcher's face (yellow–white). Electromyography (EMG) electrodes fixed to both arms and accelerometers fixed to both index fingers with flexible tape are visible in Panel D with the wires connecting the signals to a data logger located at the level behind the person. Panel E shows a fibre-optic cable, used for measuring the rotation speed of the throwing wheel. The photos A, C, D and E are taken by Tuomas Tolvanen Aalto NeuroImaging.

Examples of recording results

Eye gaze precedes hand action

Figure 3 shows the craft researchers view recorded with the camera mounted on the eye-tracking glasses. In agreement with our pilot study during clay throwing (Hari et al. n.d.) and earlier laboratory results (Flanagan and Johansson 2003), the practitioner's gaze lands at the water bucket before the hand reaches there and comes back to the clay while the hand is still on the bucket. Such pro-active eye movements are nonconscious integrative parts of accurate eye–hand

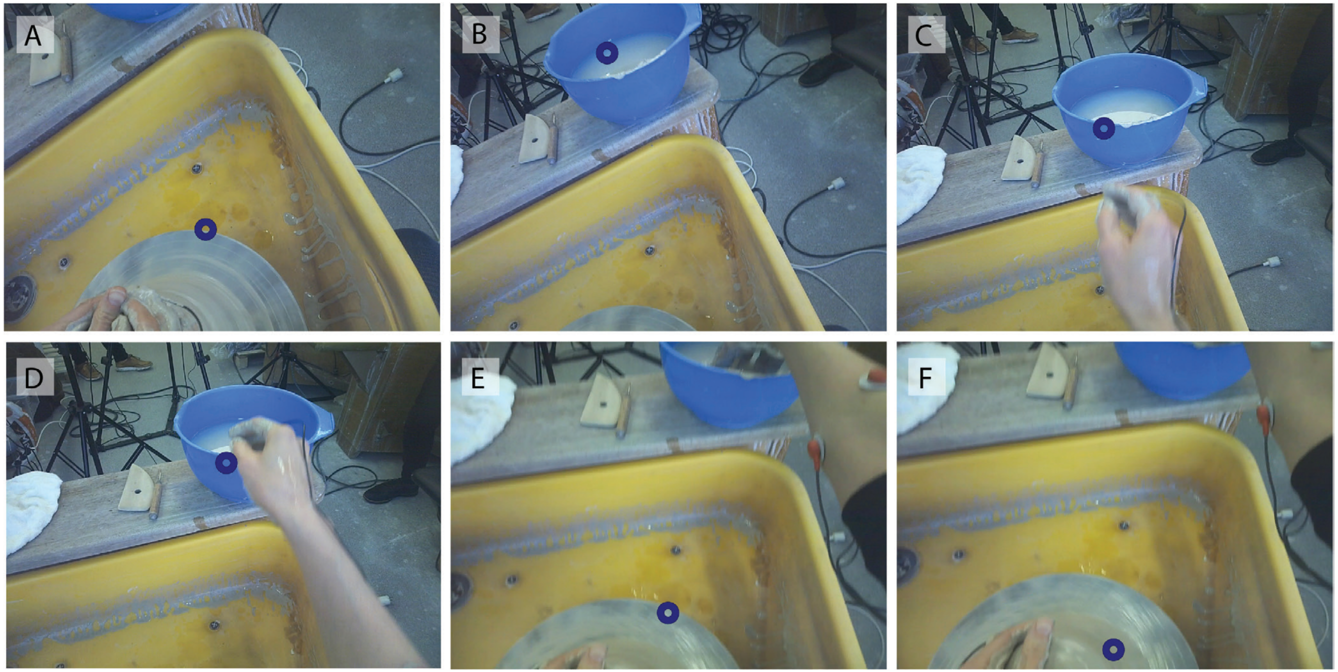

Figure 3: The experimental setup from the first person perspective, recorded via the camera mounted on the eye-tracking glasses. The location of the craft researcher's gaze in different phases of the task (A–F) is indicated by the blue circle. The figures are extracted from the eye-tracking camera and assembled by Veli-Matti Saarinen.

coordination, where the lags between eyes and hands reaching the same target were a few hundreds of milliseconds.

The gaze was not always focusing on the main action

Figure 4 shows the location of the gaze while the craft researcher was centring the clay on the throwing wheel. Contrary to what could be expected, the gaze was not always focusing on the main

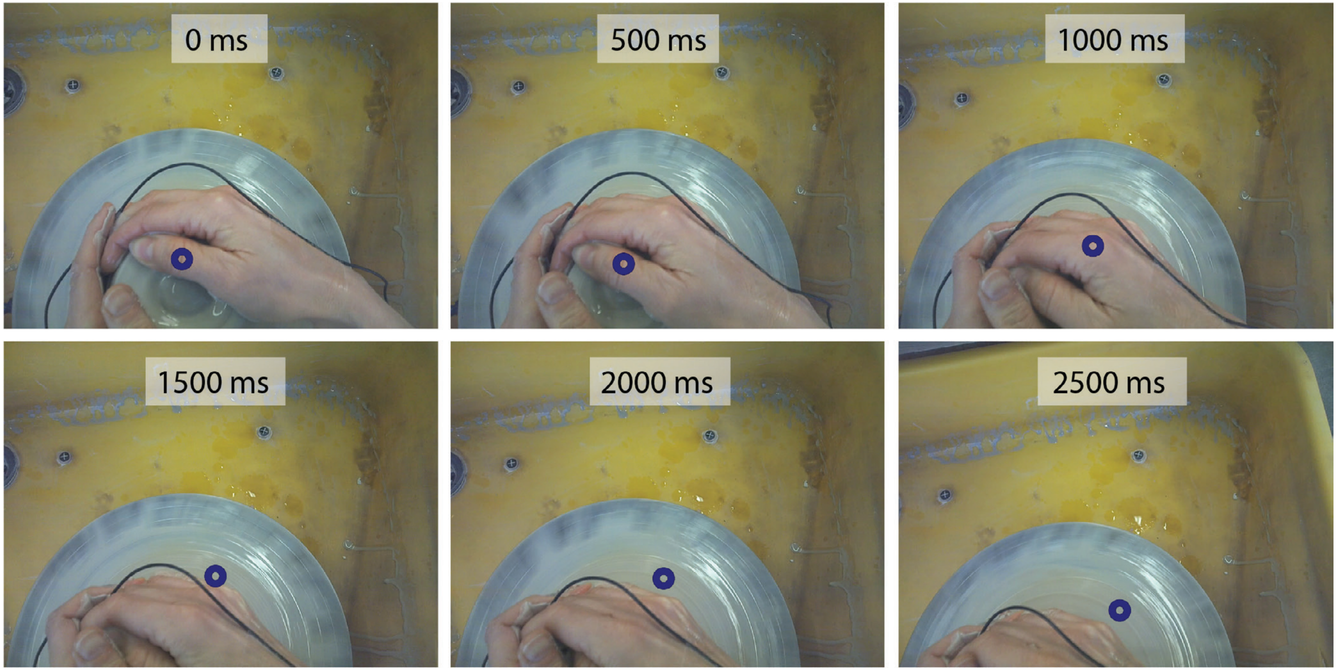

Figure 4: Still frames of the eye-camera video showing changes in the craft researcher's gaze position (blue circle) during centring of the clay. Note that the gaze position switches from the actual working point (frames at 0, 500 and 1000 ms) to the peripheral point outside the working point (frames at 1500, 2000 and 2500 ms) over the course of the task. The figures are extracted from the eye-tracking camera and assembled by Veli-Matti Saarinen.

action of the hands but sometimes rested in the periphery of the actions, likely when the researcher was concentrating on the haptic feedback of the activity. In this case, the gaze location might have revealed the shift of attention to the haptic information in the process that required less visual information.

Wheel speed slows down during the throwing process

Figure 5 shows the wheel speed over the whole about six-minute throwing session. The speed was progressively slowing down over the course of the process, being highest (about three rounds per second) during centring the clay and slowing down (to about one round per second) when the craft researcher was making the hole in the clay and thereafter rising the walls of the pot.

It is crucial to adjust the speed of the throwing wheel according to the phase of the throwing process: the higher the speed, the quicker actions are needed to compensate the centrifugal force

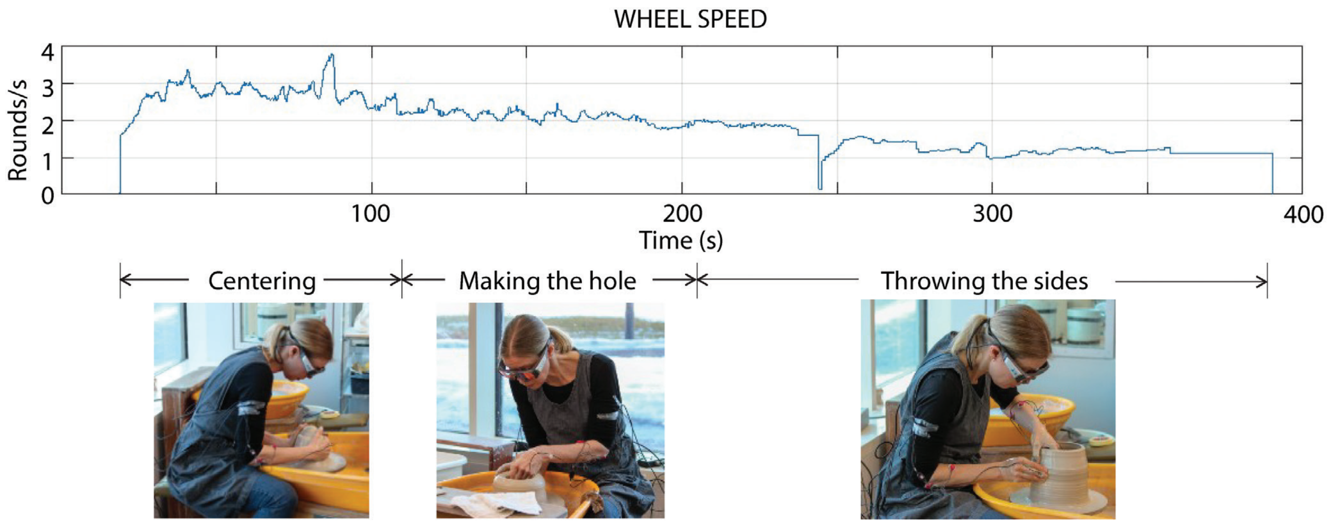

Figure 5: Wheel speed (rounds per second) over the course of about six-minute epoch starting from the initial clay centring phase to the final finishing of the clay pot. The photos are taken by Tuomas Tolvanen at Aalto NeuroImaging and Veli-Matti Saarinen made the graph.

affecting the clay on the throwing wheel. Thus, the more delicate actions are needed, the slower the throwing wheel needs to spin.

Muscle activity and finger acceleration

Surface EMG indicates which muscles are contracted and how strongly. Accelerometers can additionally inform about hand/finger position and fine control of motor actions. One motivation of EMG and acceleration measurements was to use clay throwing as a naturalistic bimanual motor-control task, informative about the continuous haptic signalling, integrating proprioceptive input from the hands and the motor commands from the brain (Bourguignon et al. 2017). Here, as well as in the pilot study (Hari et al. n.d.), these both recordings worked properly and provided good-quality data appropriate for further analysis, such as addressing brain control of fine-motor skills. These data are not reported in this article.

Discussion

The applied monitoring methods are new in the field of craft research. Traditionally ceramic craft practice has been studied from the point of view of material culture, such as art history or anthropology, or using ethnographic methods. When craft practice started to be taught in art schools and universities instead of craft workshops as master–apprentice learning, practitioners started to study their own practice more systematically, acting as practitioner–researchers who can introduce the insider's perspective into the craft processes. This, mainly phenomenological and autoethnographic, approach has furthered the research in the field of crafts enormously since its introduction (see Mäkelä 2007; Niedderer 2007; Nimkulrat 2009). With this rich tradition to lean on, an interdisciplinary approach may further craft knowledge by ways of examining aspects that cannot be studied by traditional means of craft research mentioned above. We propose that utilizing monitoring methods from neuroscience can be combined with the practitioner–researcher's introspection to give meaning to the results.

Monitoring various aspects of craft activity could help to obtain a wider scope of the craft practice itself and to help verbalizing the situational knowledge of the practice beyond what the practitioners would normally be conscious of. The practitioner–researchers in crafts might thus more accurately specify the subjective aspects of the making process and thereby be able to better communicate the skill to others. Many aspects of the making process go unnoticed while the maker tries to manage the practicalities of the processes, such as the speed of the wheel and the hand pressure applied, or the emotions during critical incidents or challenging task constraints. For example, the eye-tracking exercise in this study made the craft researcher more aware of how much she trusts her ability to feel the process of throwing clay through her hands and that sometimes during monotonous and basic tasks sight was not needed.

Previous research points to the importance of studying the practitioners' emotions in relation to their decision-making processes that are intuitive and too quick to be based on conscious reflection (Groth 2015). The experiential knowledge gained during countless hours of manipulation a material, as during learning a craft skill, is not easy to verbalize, especially amid actions. But recording the practice and reflecting on practice in a video later may help craftspeople to reflect on their own practice and to verbalize their knowledge, emotions and their reasons for their actions and decisions that happen in different sequences of crafting (Groth 2022). So, the broader our perspective is, the better understanding we could gain of our craft practice.

Future monitoring approaches in craft environments

Applied hand force

In addition to the measurements already done, it might be useful to also monitor the force that the craft researcher's hands and fingers are applying on the clay; suitable sensors are already available (see e.g. flexiforce sensors, https://www.fsrtek.com/). Training of novices might benefit from such measurements as novices typically have difficulties in apprehending the amount of hand pressure needed to use to move the clay on the wheel. Oftentimes novices tend to be too vigilant and use suboptimal force. While possible application of this type of research for the educational or practice field is still far ahead, accumulating knowledge from similar measurements from many potters could help generate a feedback aid for novices who work in the absence of a teacher.

Eye gaze

Eye direction often shows the site of attention to the environment (Henderson 2003), but it may also give clues to the thinking processes of the practitioner: the eyes are usually directed towards the area of interest and on a subconscious level the gaze precedes hand actions. (Emphasizing here the gaze target and thus the central vision is not aimed to underestimate the importance of peripheral vision.) Gaze shifts have been studied in everyday activities, such as tea- and sandwich making (Land and Hayhoe 2001). In these sequential tasks, gaze typically targeted relevant objects before hand movements took place, but also opposite sequences were possible. Afterwards, the gaze moved to the next object, on average 0.6 s before the previous task was completed.

Craft practitioners need to plan ahead, planting cues and future affordances for subsequent situations that they predict to arise later in the craft process. While this planning is conscious, compared with the automatic gaze shifts in this study, it could be interesting to reveal experienced potters' eye gaze in relation to conscious planning and detection of possible affordances in the interaction with the clay. Such studies could include analysis of eye-tracking data relative to retrospective think-aloud accounts (see also Mitchell et al. 2020).

Wheel speed

The speed of the throwing wheel is important for the success of the clay throwing and the experienced potter adjusts the speed automatically to a suitable speed. In the present study, the simple wheel-speed measurements and visualizations were interesting and led us reflect on this aspect more concretely. The wheel speed is not something that the teacher usually pays attention to, but a too high speed often leads to critical incidents for novices, especially with soft clay. In principle, the wheel speed could be indicated with, e.g., a sound in which the pitch depends on the wheel-rotation speed so that a novice might more easily pay attention to wheel rotation in the absence of a teacher. Of course, one also needs feedback on suitable speed at each step of the task. In the current study, the wheel speed was monitored mainly to test the feasibility of this measure.

Thermal camera recordings

The temperature changes of clay over the course of the throwing activity are rarely discussed, but in the current study it became concretely visible how the hands and friction warm the clay surface. However, thermal imaging has a far more interesting potential application in craft research. Some emotions affect the skin by increasing or decreasing face temperature, and for example face blushing is visible in the infrared radiation picked up by the thermal camera (Ioannou et al. 2017). Such temperature changes are caused by vasoconstriction and vasodilatation in the skin and by emotion-related sweating. Consequently, thermal imaging has been used to study physiological responses related to startle responses, empathy, guilt, embarrassment, sexual arousal, stress, fear, anxiety, pain and joy (Ioannou et al. 2014). For example, temperature of the nose decreases in stress induced by mental workload. Modern thermal imaging can track relatively rapid, about 1–2 s, changes, as was the case with startle responses (Sonkusare et al. 2019). While such variations were not seen in the current experiment, nor specifically searched for, at a higher camera resolution and by applying different conditions and emotion annotations such emotion-monitoring could be possible and allow practitioner–researchers to track for example their decision-making processes in relation to emotions. Interestingly, heart and respiration rates can be extracted noninvasively from the thermal-camera videos (Barbosa Pereira et al. 2018).

Potential of action measurements to accumulate general knowledge

Naturally our approach to analyse distinct, although interdependent, physiological measures only sample a part of the whole process of a natural clay throwing act. However, if the current measures were combined with qualitative data, such as videoed interviews of the practitioners, a fuller picture might arise of the decision-making processes for example in stressful situations where one needs to make quick decisions on the basis of intuitive knowledge. It would also be interesting to compare experts and novices in these situations.

Documented and analysed subjective narratives of craft experience and knowledge are important to understand the qualitative dimensions of craft practices; however, as singular and individual pieces of information they do not necessarily accumulate generalizable knowledge on their own. By combining action monitoring with subjective narratives of the craft practitioner and by repeating the experiments in a large group of subjects, a deeper understanding of various aspects of the craft practice might emerge. This approach would be similar to the observations that the general patterns of self-reported bodily feeling maps of emotions are consistent across a variety of experimental conditions and the individuals' nationalities (Nummenmaa et al. 2014; Volynets et al. 2020). Specifying the general patterns of craft practices is a challenging task but worth pursuing as it could help connect theory and practice and lead, in the long run, to even better practices and related education.

Joining forces across disciplinary borders

Many research problems do not appear as packages that fit into a single discipline, especially because the disciplinary borders are historically shaped and may not serve the topic of a certain research question (Stember 1991). In such situations interdisciplinary efforts are not only encouraged but adamantine. In many fields of research, the landscape has changed drastically in the last decennia so that interdisciplinary mindsets and research teams are needed to tackle the problems. It is well established that new knowledge can often be found by exploring areas in between disciplines, as we wish to happen between crafts and neuroscience. Although the main interests of some disciplines may be so far away that common research problems are not evident, unexpected mutual interests may emerge if researchers just start a dialogue and to work together, trying to clarify their concepts, methods and goals.

As research collaboration over disciplinary borders is increasingly topical, many attempts have been made to visualize the different collaborative settings (Morse 2007; Refsum Jensenius 2016; Nimkulrat et al. 2020). We briefly outline features of different levels of collaboration between disciplines, as schematically presented in Figure 6. These thoughts are largely rooted in one author's decades-long experience of running a highly multidisciplinary research team unravelling human brain function (Hari 2021a, 2021b).

In unidisciplinary (intradisciplinary) work (first panel in Figure 6), researchers ask specific questions for which they do not need collaboration with other disciplines. Examples might be theoretical work in mathematics, with no interest in direct applications. Researchers from other fields are politely tolerated, as any human beings, but not specifically needed for own work.

In multidisciplinary interaction (second panel from left in Figure 6), researchers address others, but without too much listening to others' views. Multidisciplinary groups may be collected for projects of limited duration, but in the absence of a permanent research team the obtained knowledge does not cumulate. Such collaboration risks to become friction-prone because of various power structures; for example, well-funded researchers may buy researchers from other disciplines to work for them. Importantly, the result of multidisciplinary collaboration is only sum of its parts (1 + 1 = 2).

More integrative collaboration occurs in interdisciplinary teams (third panel in Figure 6) where researchers already talk intensively across disciplines, for example exchanging methods, views, knowledge and skills, but still mainly for their own benefit. The interdisciplinary work has some – but not necessarily high – additive value (1 + 1 = 2+). Considerable additive value is possible only if the participants have some overlap in their knowledge and skills; otherwise the collaboration will not help either party to rise above their own achievement level. Building up such an overlap may

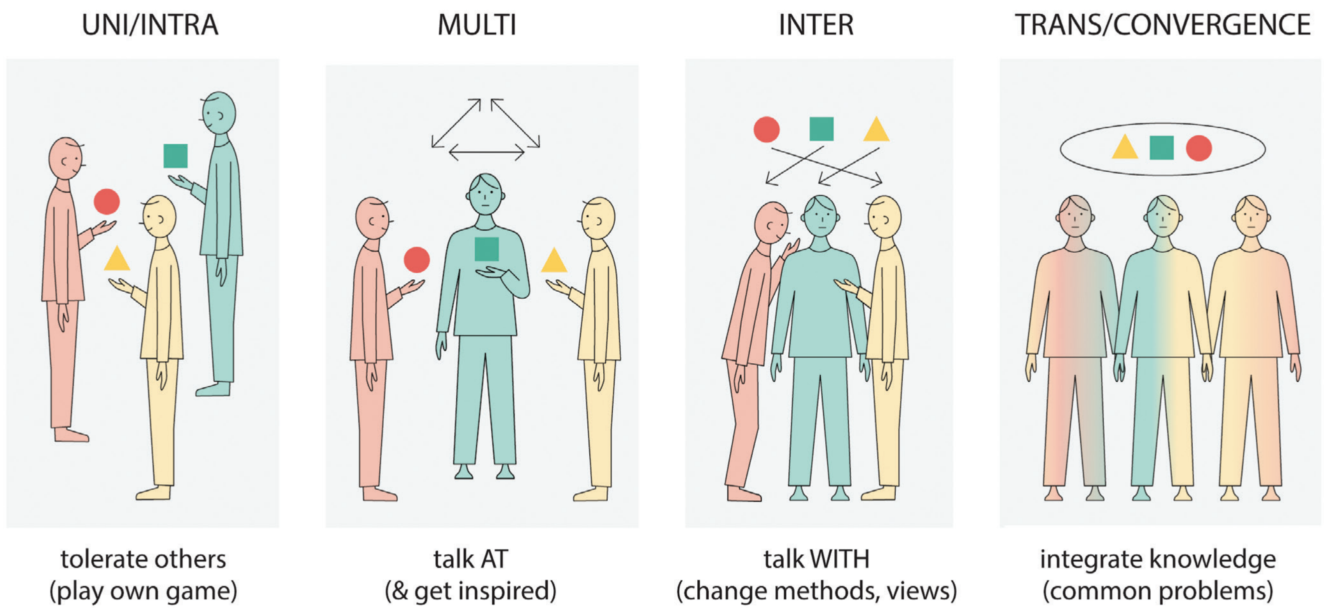

Figure 6: Levels of collaboration between disciplines (modified from Hari 2021a, 2021b).

take years, and the resulting collaboration can be spoiled in a moment by, e.g., thoughtless organizational changes.

When trying to attack wicked problems (Rittel and Weber 1973, 1984) that are difficult to define and difficult to solve, interdisciplinarity is not enough, but one should strive for transdisciplinary or, better, convergence research (see Sharp et al. 2016; Roco 2020) that aims at integration of diverse perspectives, intellectual insights, knowledge and understanding (fourth panel in Figure 6). Here the potential benefits are high (1 + 1 >> 2). Importantly, all members of the team now have a common goal. Convergence research, as the most challenging form for collaboration, requires changes in attitudes of researchers, organizations and even funders.

Members of convergence research teams must invest in effective communication and have a wide spread of skills and knowledge, still with deep roots in own special areas. Such researchers are often described as T-shaped knowledge professionals (Barile et al. 2012). The 'vertical stroke' of T-shaped persons refers to deep knowledge and expertise in one field. The 'horizontal top line' of the T represents the practitioner's additional ability to apply their knowledge in a wide range of situations and to collaborate and interact across disciplines (Groth et al. 2020).

Becoming a 'convergence researcher' is easiest if the education starts early. Several universities now integrate students in either interdisciplinary courses or even interdisciplinary study programmes, many of which include creative practice (see e.g. Aalto University's university wide art studies UWAS courses and Royal College of Art, just to mention a few).

In our current research, we are far from convergence research and have just started to scratch the surface of collaboration between craft sciences and neurosciences – two disciplines that are so far from each other that shared problems have been unusual. However, opening for mutual collaboration is a strategic move towards broader overlap and contact between these disciplines. Only by engaging in such collaboration do the real demands of this type of efforts become tangible and the mutual interests clarify. We need a long exposure of the different epistemologies and mindsets that prevail in interdisciplinary collaboration.

Conclusions

The activities presented and discussed in this article evolved from mutual interests and curiosity but may open new avenues of collaborative efforts between craft sciences and neuroscience and narrow the split between them to enrich both parties. During the dialogues around our small experiment, some possible starting points emerged for further enquiries. For neuroscientists interested in bringing their methods and experimental setups from highly controlled laboratories towards more natural settings, clay throwing seems to provide a nice bimanual motor task that is informative about the continuous haptic signalling that integrates proprioceptive input from the hands with the motor commands from the brain. Thermal recordings, eye tracking and other physiological monitoring methods introduced in this article can be useful for documentation purposes, as well as for verbalization of the experiential knowledge and expertise of the practitioner during clay throwing. In addition, it might allow practitioner–researchers in crafts to become aware of unconscious steps in the making process. Consequently, we would encourage a wider use of various action monitoring approaches during craft practice to accumulate information obtained from persons and to narrow the gap between humanities and natural sciences, both methods-wise and conceptually.

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