Reflection on Tacit Knowledge – Effect of Providing EMG Visualization on Reflections on Throwing Clay

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Abstract
Craft practitioners rely on reflection to train and improve their skills. The lack of media to represent and communicate their tacit knowledge makes reflection difficult, especially if this reflection happens after the fact. This paper presents a set-up that tracks and visualizes muscle activities of potters when throwing on the wheel. We use this set-up to investigate the effect of the visualization of potters' muscle activities on their retrospective reflections on their own practice. We conducted a preliminary user study with three expert potters. The preliminary results suggest that externalizing the once implicit muscle activities alters potters' reflection of their own practice and can potentially serve as a medium to communicate the tacit knowledge involved in throwing.

Author Keywords
Digital Craft; Embodiment; Reflection; Tacit Knowledge.

Introduction
In craft practices, reflection is thought to be an important activity in which crafters think about the "things done and not done" [13] in their practices to improve their skills. Different reflection mechanisms such as video recordings and capturing software for certain practices have proven to be an effective way to

enhance the reflection experience and quality [7][9]. But craft involves a lot of tacit knowledge which is largely embedded in the doing rather than any explicit representations of the knowledge. The problem of this kind of knowledge is that "we can know more than we can tell" [4] and craft's various practices pose their own challenges for a reflection-based approach. Schön proposed a double concept of reflection, which allows this type of reflection on the tacit aspect of the task [2]. His "reflection-in-action" concept has received some criticisms and concerns regarding its vague definition of "in-action" and the feasibility of adopting this type of reflection in actual practices [1][2]. Yet, Schön's differentiation between "in-action" and "on-action" reflections provides important insights regarding the reflection context. If the reflection context enables the access to tacit aspects of the practice, how can we adjust the reflection itself to support this? In this paper, we present a system that captures and visualizes the Electromyography (EMG) data of potters. EMG data records muscular activity by sensing electrical potential in muscle cell activation. It is widely used in medical and neurological research. We conduct a preliminary study to investigate the effect of the provision of EMG data on the "on-action" reflection experience. There have been attempts to capture the tacit knowledge of pottery masters by tracking their muscle activities and the results are promising. One study collected EMG data from a master potter and a novice potter while centering. It showed a significant difference between the EMG data of the master and that of the novice. Moreover, the novice's EMG data was getting closer to the master's after receiving training [12]. Our approach expands on the tracking to look into the value of the *reflection* as component of eventually teaching tacit knowledge through new interfaces.

Background

Tacit Knowledge in Pottery

Polanyi coined the term "tacit knowledge" to refer to the type of knowledge that one gains by embodied learning. It stands in contrast to the explicit and external knowledge (e.g. instructions) which, according to Polanyi, can only be extended after gaining the tacit knowledge [4]. Although the term remains problematic, [3] we decide to adopt the original definition of tacit knowledge proposed by Polanyi as it best reflects our research problem.

Throwing, the construction of a ceramic object on the spinning wheel, is an important technique in pottery and has been identified as an - at times almost poetic - moment of tacit knowledge at work [14]. To this day, it plays an important role in the education of ceramicists. This particular tacit knowledge allows a potter to produce a set of emergent hand-body movements while working with the clay as it spins on the potter's wheel. From a cognitive perspective, the hand movement is a result of thinking, planning, and execution of the plan through motor functions. As other studies have noted for different crafts [5] the thinking and planning in such a practice depend on doing the action itself. Without that practice, necessary knowledge cannot be acquired. Although potters are able to describe the process verbally, a major part of the knowledge resides in the actions. If knowledge in throwing remains tacit, how can digital media help potters to communicate this practice?

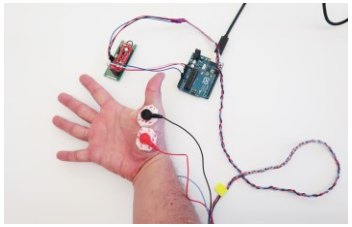


Figure 1. The illustration of the system design when in use.

Digital Media As Reflection Mechanisms in Craft Practice

With the development and application of digital technologies, researchers have successfully experimented with capturing tacit aspects of some craft skills such as pottery [12] and paper-making [15] using different types of digital media. By capturing the motion data (e.g. through EMG data, Laser Range Sensor data), and integrating them into visualization systems, researchers were able to observe some learning effects on amateurs' performance when the systems were used to directly guide the amateurs' actions. The visualization of the motion data have demonstrated their potentials for being used to facilitate tacit learning, but the learning processes using those visualizations remain a part of the *action* process. They are rarely used for *reflection* purposes in which explicit knowledge about the skills can emerge via critically examining the tacit experience.

Reflection is central to learning and dealing with real-world situations regarding any practice. [2][6][7] Schön introduced the term "reflective practitioner" to describe the way in which practitioners often think about their actions and situations when applying knowledge. But they not only apply knowledge, they also gain new, practical knowledge from the reflection process. Schön considered reflection as a way for practitioners to "surface and criticize" the tacit understanding they gained in actions. This can happen either during the action (as "reflection-in-action") or after the action (as "reflection-on-action").

Schön's framing reveals a key characteristic about reflection: reflection, as an activity, is highly situated. By changing the context and conditions in which practitioners perform the reflection, the outcome (i.e., their understanding and experience of their own practice) changes. For example, there is plenty of evidence from educational technologies suggesting that the provision of multimedia documentations, such as video recordings, facilitate the reflection process and learning [11]. Likewise, in craft practices, there are efforts focused on providing new mechanisms for crafters to reflect on their practices, make sense of the materials and the situation, and enhance the experience of the craft [8][9][10]. Among these efforts, digital media have demonstrated great flexibility and diverse expressive characteristics [8] in enhancing the reflection experience and subsequently the experience of the craft.

System Design

Our system consists of an activity-sensing hardware part and a visualizing software part that logs the data and presents it after the practice (Fig. 1). Both are used to affect the "reflection-on-action" of ceramic artists after throwing a basic bowl on the wheel. The hardware part is assembled from a Myo EMG sensor and an arduino microcontroller. The Myo attaches to one of the core muscles in the hand needed for throwing, the abductor pollicis brevis (APB). The connection points where the electrodes are attached are sealed using film tape to ensure water resistance. An arduino script registers the muscle activity data collected by the EMG sensor, sends them via a Serial connection to a processing script, which records the data into a text file and visualizes them in relation to elapsed time.

Method

The study was set up as a proof-of-concept study to explore conditions for a larger and more comprehensive

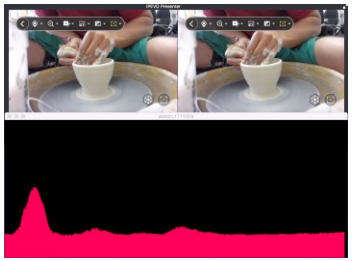
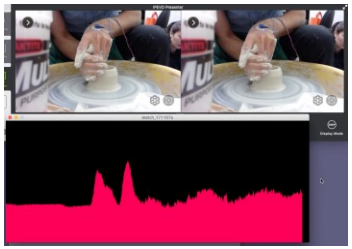


Figure 2. The reflection material used in Condition 2 (Synchronized video recording and EMG visualization).

Condition 1. Only the video recording



Condition 2. The video recording and the EMG visualization

Table 1. The reflection materials used in the two conditions.

approach. A total of three participants were recruited using snowball sampling method. Each participant had at least 5 years of experience in ceramics. In the study, participants were asked to wear the sensing system and throw a bowl shape as similar as possible to a given example shape. The throwing process was recorded using a web camera connected to the computer and crafters' muscle activity data were recorded through the Myo sensor. For our control, these data were visualized in real-time in a window on the same screen (Fig. 2). Neither the video recordings nor the muscle activity visualizations were shown to participants during their throwing practice.

Once the participants completed the throwing practice, they were asked to do the reflection task in think-aloud comments in two different conditions that varied in their use of assisting visual material (Table 1). In the first condition, participants were asked to reflect purely on the video recordings of their practice. In the second condition, participants reflected on the same practice based on both, the video recordings and the muscle activity visualization. The video recordings and the muscle activity visualization are synchronized so that participants are able to correlate their actions with the EMG visualization. Following the reflections, participants were prompted to discuss their overall experience.

Hypotheses

To examine the effect of the EMG visualization, we generated the following hypotheses:

- Hypothesis 1: The EMG data will lead to a perception change: potters are going to shift more of their attention from objects to actions.
- Hypothesis 2: The EMG visualization will emphasize embodiment and lead to more reflections covering qualitative aspects of the action.
- Hypothesis 3: The EMG visualization will promote more engaging reflection experience.

Results and Discussion

Data was collected from 6 reflection sessions (audio sessions). They were transcribed and analyzed. We adopted a top-down analysis method of the recorded reflections that looked at two dualities: the duality of the internal (i.e., the actions) and the external (i.e., the objects), and the duality of the explicit (i.e., the visible actions) and the implicit (i.e., pressure, quality of the actions). In addition, we were interested in how participants perceived the visualization graph. A total of 10 codes were used in the data analysis (Table 2). Two coders independently applied this scheme to the transcription data from the crafters' verbal reflections in both conditions. After the initial coding, they discussed the results to resolve conflicts that were caused by the wording of the codes and coding errors (e.g. errors in counting). We reached an inter-coder reliability of 97.1% and a total of 538 segments were agreed on and used in the following analysis.

Category	Codes	Examples
Action-related reflection on practice	Actions performed in the practice	"open",
	The direction of the action(s)	"up"

Category	Codes	Examples
	Hand/body parts	"thumb on my left hand"
Object-related reflection on practice	Part(s) of the object, without an indication to its location	"shape"
	Part(s) of the object, with an indication to its location	"the bottom"
	The texture of the object/material	"wet"
Quality of the action(s)	Quality of the action(s)	"consistent"
Mentions of Pressure	Pressure	"pressure"
Graph	Graph features	"dip"
Reflection Activities	Activities happened in the reflection phase	"see"

Table 2: The coding scheme used in the qualitative analysis

Overall, participants made more comments in video-only Condition 1 than they did in the combined media Condition 2 (n_{1total}= 323, n_{2total}= 215). We attribute this difference to the order of the reflections. Because participants were reflecting on the same recorded practice twice, they might consciously or unconsciously skip details during the second review. Given the setup of our study, this remained problematic. However, to reduce the size of the order effect, we avoided comparing the absolute values of counts across conditions in the testing of the hypotheses. Instead, we used relative measures (i.e. percentage) to address the changes between conditions. Likewise, given the limited study size our discussion remains largely indicative.

In order to test Hypothesis 1, we calculated the percentage relation of verbal statements by crafters that related to actions versus those that related to objects. Through this measure, we examined whether any percentage change happened between conditions. In Condition 1, during which participants reflected only on the video recordings of their practice, their action-related segments account for 62% of the total mentions of actions and objects. The object-related segments account for 38% of the total mentions. In Condition 2, the action-related segments accounted for 77% of the total mentions of actions and objects, and the object-related segments for 23% of the total mentions. We see an 15% increase regarding the action-related segments in Condition 2, in which the EMG visualization was provided. We read this as indicative for a support for our first hypothesis as reflection on the activity shifted more into the foreground in Condition 2.

Regarding the test of Hypothesis 2, participants reflected verbally in different ways on the quality of the action based on the video recording and the EMG visualization. Words like "similar", "steady", "consistent" were used to describe the quality of actions in the review of the video recording and the changes in the visualization. In total, 19.5% of the total comments participants made in Condition 2 were regarding to the quality of the action ($n_{2quality}$=42)

compared to only 6.5% in Condition 1 ($n_{1quality}$=21). Thus, our second hypothesis appears to be supported: The EMG visualization led to more reflection on qualitative aspects of the action. Participants also made explicit inferences of the quality of their practice based on the quality of the visualization. For example, P1 noted about the steadiness of the curve in the visualization: "That's interesting, really steady kind of curve. That feels helpful. That's really what that feels like."

Regarding Hypothesis 3, the engagement of reflection is measured by vocabulary indicating additional activities taking place in the reflection process that are provoked by the reflection materials such as "see here", "I think", "I feel"). The fact that participants not merely described what they were doing (Descriptive reflection) but also were actively making sense of their own practice (Dialogic reflection) by having conversations with themselves indicates that participants were engaged with the reflection itself in a deeper level [16]. We found participants made more comments about activities associated with reflection itself in Condition 2 ($n_{2reflection}$=23, accounting for 10.7% of the total comments made in Condition 2) compared to the comments they made in Condition 1 ($n_{1reflection}$=5, accounting for 1.5% of the total comments made in Condition 1).

This study remains indicative, due to its size and set up. But it allows us to project the possible value of such a system. In sum, it indicated that the added visualization of participants' EMG data affected the reflections. The EMG visualization appeared to be useful in promoting more reflections on the actions (Hypothesis 1) and the quality of the actions (Hypothesis 2). The provision of the EMG data also promoted more activities such as feeling and thinking that were beyond the throwing itself, as indicated by the participants, in the reflection sessions, which suggests that participants were more engaged in the reflection (Hypothesis 3).

Summary and Future Work

The paper illustrated a system that utilizes digital media to support a "reflection-on-practice" for the particular craft of throwing pottery on a wheel. The results are largely indicative due to the low number of participants and the uni-directional order of the experiment. The evaluation balances this through a percentage-based close reading analysis of voice reflections to reduce the impact without compromising the ability to test the hypotheses. We are planning on including more participants and test in reversed conditions to eliminate the ordering effect. The preliminary results confirm past work in that the reflection, as an activity, is clearly a situated one. By providing different reflection materials, practitioners' perception regarding their practice changes. Besides the successful testing of the hypotheses, this study provides early evidence that encourages further exploration in tracing and communicating tacit knowledge at work in craft reflection. By externalizing/visualizing the muscle activities, the system provides information about actions that is otherwise inaccessible. This creates opportunities for practitioners to examine the tacit aspect of their practice and obtain a richer experience in both the practice and the reflection.

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