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# An Empirical Study of Understanding in Order to Act and Acting in Order to Understand in Digital Design Practice

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We present an ongoing empirical study into a distinction between two kinds of purposeful action: understanding in order to act and acting in order to understand. This distinction is referred to in several design theories and has received limited empirical attention. One such effort investigates Tetris play and labels the two kinds as pragmatic and epistemic actions. With Tetris being characterised by simple rules and a well-defined goal, the question arises whether it offers a suitable context to account for human action in the context of design, given its ill-defined goals and often-conflicting requirements. To address this question, we are conducting a lab study of individual designers concurrently thinking-aloud during digital design processes. We analyse data acquired in this setting using the linkography method. Our preliminary analysis shows that pragmatic design objectives frequently lead to epistemic fulfilments (or dead-ends) and vice versa. In total, we identify six design episode categories. Numerous design episodes we observed fall into different categories when analysed across different observational time frames.

KEYWORDS: digital design, linear and circular processes, pragmatic and epistemic actions, protocol analysis, linkography

RSD TOPIC(S): Cases & Practice, Modelling & Mapping, Architecture & Planning

## Presentation background

Several authors distinguish between two kinds of purposeful human action using varying terms. The first kind is understanding in order to act (Glanville, 2014). The second kind is acting in order to understand (ibid.). The first describes purposeful action as linearly goal-directed, in which planning (i.e., understanding) is a prerequisite to subsequent execution (i.e., acting). Schön (1983), Suchman (1985), Kirsh and Maglio (1994), and Glanville (2014) note that this linear view has been prevalent across early theories of design. More recent design theories also acknowledge the second kind of human action and the mutually-complementing interrelation of both kinds to form circular conversational and reflective theories of purposeful human action in general and design in particular (Schön, 1983; Glanville, 1999, 2014). To date, however, the circular interconnection of both kinds received limited empirical attention, with one substantive study having been no more than tangential to design. That study was carried out and documented in a series of articles published by David Kirsh and Paul Maglio in the 1990s and early 2000s. Investigating human actions in the context of Tetris play, the team labelled the two kinds of human action as pragmatic (understanding to act) and epistemic (acting to understand) actions (Kirsh & Maglio, 1994; Kirsh, 1995, 2006, 2008).

## Pragmatic and epistemic actions in Tetris

In Tetris play, the goal is to complete and thereby dissolve horizontal rows formed of irregularly-shaped Tetris pieces falling from the top and stacking up at the bottom of the game's visual interface. While each piece is falling, the player can move the piece horizontally and change its rotation. The game ends when the entire interface height is clogged up with incomplete, hence undissolved rows, and no more pieces can enter from the top. Over time, the game speeds up, which results in increasingly challenging gameplay (Kirsh & Maglio, 1994). Kirsh and Maglio refer to the fall and landing of each Tetris piece as a Tetris "episode". In each episode, the goal (or multiple equally desirable goals) and the shortest path to attain the goal are unambiguously clear in principle. However, effective goal identification and pursuit of the direct path towards the goal depend largely on player experience and the game's speed at a given time. According to linear theories of human action, players are expected to understand the goal and its

shortest path prior to manoeuvring Tetris pieces (Kirsh & Maglio, 1994). Kirsh and Maglio (ibid.) utilised a bespoke implementation of the game and recorded actions performed by subjects to test this assumption. In recording their subjects' gameplay actions, they relied on 'episodes', 'placement of Tetris pieces', 'goals', and 'paths' as units of analysis (or 'metrics' in their terms) to categorise said actions as either pragmatic or as epistemic.

In Kirsh and Maglio's analysis, pragmatic actions are those that lead to goals directly. They reason that any such action is based on an understanding of the goal and the shortest path towards it and is carried out in order to attain the goal along that path. Epistemic actions, by contrast, are actions by which players do not immediately and directly advance towards the goal. They see these moves as ways by which players probe the game environment to understand possible goals and actions to achieve them (Kirsh & Maglio, 1994; Loader, 2012) and postulate that epistemic gameplay actions in Tetris improve performance (Maglio & Kirsh, 1996). In theorising about epistemic actions, Kirsh and Maglio depart from earlier linear and reductionist assumptions that "the point of action is always pragmatic" and that 'understanding' always precedes 'acting' (Kirsh and Maglio, 1994, p. 526). They argue that these earlier "one-sided" views create "an undesirable separation between action and cognition" (ibid.) and reject linear planning models in favour of circular ones in order to describe purposeful human action. With Tetris being characterised by simple rules and a clear goal definition, the question arises whether this game offers a sufficient and suitable context to account for human action in the context of design, with its ill-defined goals and often-conflicting requirements (Rittel and Webber, 1973). Figure 1 below illustrates the application of Kirsh and Maglio's distinction in the (digital) design context.

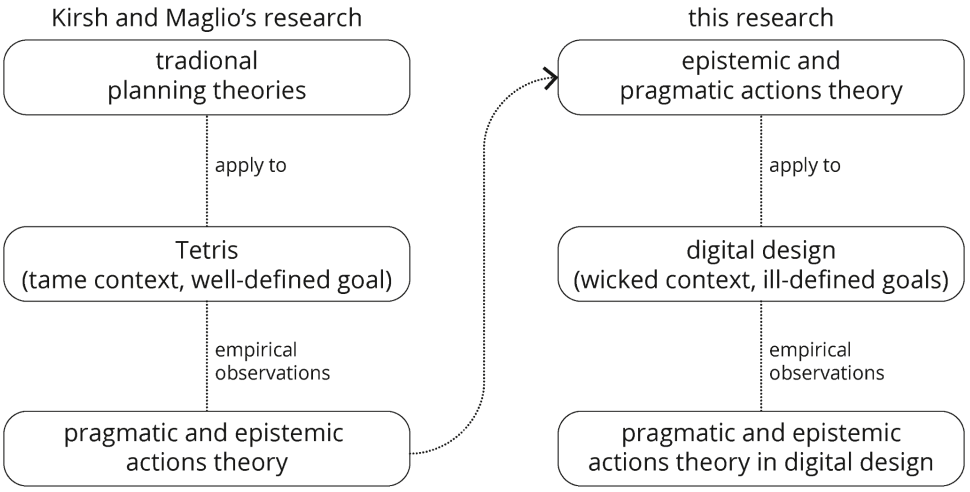


Figure 1. Application of Kirsh and Maglio's theory into the digital design context.

## Methods

To address this question, this project examines the distinction between pragmatic and epistemic activities in an empirical lab study of individual designers engaged in digital design processes. We observed six subjects (two digital design novices, two with intermediate digital design skills and two with advanced digital design skills) engaging in the design of a retail shelving and space partitioning system in Rhino3D and Grasshopper. The design brief asks for a panelled approximation of a double-curved back surface. This requires subjects to devise and implement suitable geometry rationalisation strategies during the design process.

Following carefully supervised technical setups, the six design processes were observed remotely via video conferencing software and lasted between 60 and 105 minutes. Employing concurrent think-aloud protocol analysis methods (Ericsson & Simon, 1980; Kan & Gero, 2017; Lee et al., 2020), we encouraged each subject to verbalise their thought processes and actions throughout their design process. The main investigator was present throughout all six design processes, generally remaining silent but offering perceptive ears to the verbalising subjects, reminding subjects to keep verbalising when necessary, and acquiring a live, near-participatory appreciation of each design development. We also collected qualitative data in the form of audio and video

recordings as well as sketches produced by the subjects during their design processes. We transcribed and consolidated each of the six data sets into two parts: records of observable actions in the external environment (freehand and digital sketching as well as interactions with Rhino3D and Grasshopper) and records of think-aloud thought processes verbalisations.

## Pragmatic and epistemic episodes in digital design processes

Unlike Tetris, with its pre-defined metrics, (digital) design is characterised by ill-defined, open-ended goals (Rittel & Webber, 1973). Accordingly, design processes cannot be segmented into predetermined temporal episodes with known and well-defined goals (Kirsh & Maglio, 1994; Kirsh, 2006). To identify the two types of action and to understand their interplay in the design process, some degree of subjective interpretation is therefore necessary. In our case, this subjective interpretation is based on a design-cybernetic, constructivist approach to design research in which we recognise that we "can never really know what goes on in somebody else's head" and can only interpret what is being externalised (Pörksen, 2004, p. 40; Fischer, 2008). Therefore, our analysis aims to attain a "close-enough" understanding of each subject's design activity (Fischer & Herr, 2019, p. 16). This reflects the view that meanings of utterances are never truly shared but constructed subjectively and negotiated until resonance in conversation appears good enough to allow moving forward as if the conversants were talking about the same (ibid.; Glanville, 1996). Specifically, we determine a justifiable segmentation of design episodes – the units we analyse with regard to their pragmatic or epistemic objectives and fulfilments. For this purpose, we analyse our acquired data sets using a coding scheme (see Figure 2) and the linkography method (discussed below). The coding scheme builds upon Schön's (1983) and, in particular, Glanville's (1999) descriptions of design as a circularly causal conversational process between an internal self and an external other. In our analysis, a design episode is a discernible and demonstrable cycle that starts with a subject's verbalisation of their setting of an objective, followed by "(experimental) moves" towards the fulfilment of this objective, followed by a verbal reflection on the extent to which the objective has been fulfilled, which then leads to the start of another discernible and demonstrable cycle with the same pattern (Valkenburg, 2000, p. 58; Schön, 1983).

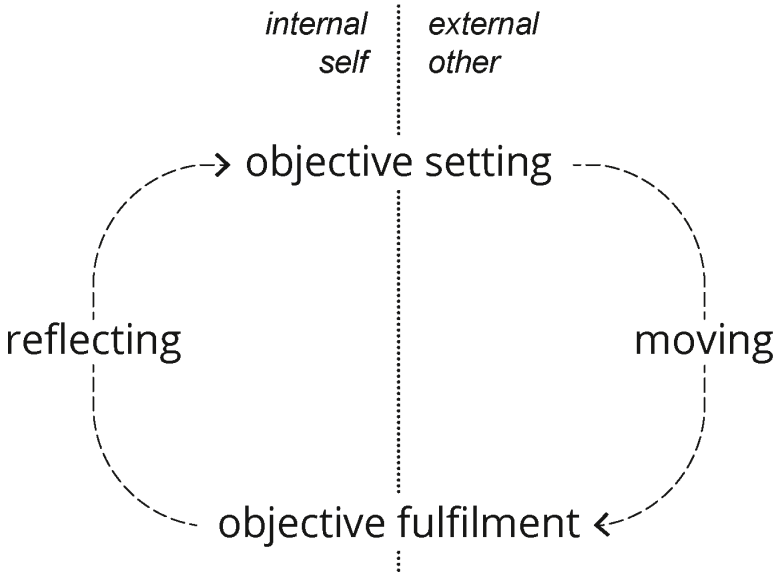


Figure 2. Partial coding scheme.

We transcribe and segment our records of the observed design processes, code the resulting data sets in qualitative terms, and record our interpretations of significant coded events in protocol tables along a vertical time axis, as shown in part on the left of Figure 3. In these tables, we further examine and categorise pertinent verbalisations of design objectives as well as their possible fulfilments as either pragmatic or epistemic, based on our subjective interpretation and close-enough understanding of each design process. If, for example, a subject sets an objective followed by speculative moving ("What if…?"), then we categorise the said objective as epistemic. However, if the subject verbalises an objective that does not involve speculative moves ("Let's do x."), then we categorise the objective as pragmatic. Moreover, to categorise fulfilments, we examine instances in which the subject reflects on their designed 'geometry' (i.e., 'proposal' or 'solution') present in one of the observed external environments. If, for example, we observe the geometry remaining 'fixed' (i.e., to stop evolving) and forming a part of the overall design artefact, then we label it as a pragmatic fulfilment ("That's good enough, let's keep it."). If, however, we observe the geometry to be a snapshot of an ongoing

process and subject to further re-consideration and change, then we label it as an epistemic fulfilment (“I see a way to improve this.”).

The column on the right of the table in Figure 3 shows the linkographs produced from our transcripts of the design process recordings. Linkography is a well-established method to graphically analyse the how and what of design processes (Goldschmidt, 1990, 2014). It is a diagramming approach to map and link ideas and actions over time, offering a bottom-up and detailed depiction of a design activity within a specific time frame (ibid.). Based on analyses of the initial version of these linkographs, we discern, categorise and notate ‘links’ between set objectives and fulfilments, or the other way around, thereby determining design episodes analytically. We then revise the linkographs to represent pragmatic objectives and fulfilments as squares and epistemic ones as circles. We have discerned a minimum of 70 and a maximum of 110 design episodes in the six protocol data sets.

| transcribed raw data | | | pre-analysis phase | analysis phase | | |
|---|---|---|---|---|---|---|
| Time | Partial verbatim data | Observable actions | Qualitative description | Analysis and descriptive categorisation | Codes | Linkograph |
| 00:15:43 | What if I will try designing different stacking configurations of the compartment units for the front side of the shelving system. I think I will generate around 3 configurations and choose from one of them later. | In Rhino, the subject permutes different compartment units in order to design a possible stacking configuration. | In this phase, the subject is designing different stacking configurations of compartment units. They verbalise an aim to generate three different stacking configurations from which they will choose from later during the design process. | It appears that the subject aims to generate different stacking configurations of units. The design objective can be described as **epistemic**. | E.O | |
| | | | | [RH] The subject is stacking and arranging different units together to form different clusters. | M | |
| | | | | Reflecting on different geometry. | R | |
| 00:16:31 | Hmm... I will do some modifications to this design in the later stages. | Generates three stacking configurations of compartment units. | | | E.F | |
| 00:25:18 | Now that I have a configuration, I can extrude it to create a solid. I will just do this manually... No need to use Grasshopper here. | In Rhino, the subject extrudes the 2D curves of the stacked units. | In this phase, the subject verbalises an aim to generate a solid extrusion of a previously generated outcome. | In this phase, it seems that the subject aims to extrude the 2D curves. In my understanding, this design objective is **pragmatic.** | P.O | |
| | | | | [RH] The subject is performing solid extrusions of the 2D curves. | M | |
| | | | | Reflecting on the geometry. | R | |
| 00:31:43 | This actually works and is looking good enough. I'll keep it as it is. | Generates a solid extrusion from the 2D curves of the stacked compartment units. | | | P.F | |

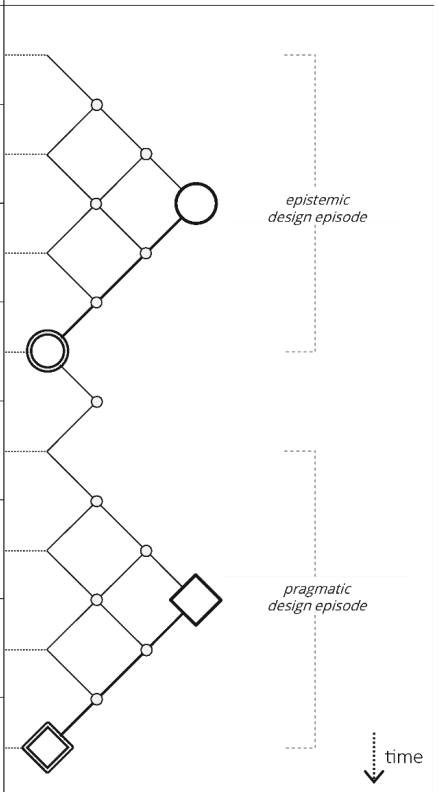


Figure 3. Partial protocol table and linkograph with examples of epistemic and pragmatic episodes.

## Preliminary findings and contributions

Our initial linkographic analysis offers several insights into the interplay of both kinds of action – taking into account the ill-defined and subjective nature of design and, based on that, the absence of conveniently clear-cut units of analysis that are discernible in Tetris. In our data sets, we identify numerous design episodes that begin with epistemic objectives and end with epistemic fulfilments, as well as numerous design episodes that begin with pragmatic objectives and end with pragmatic fulfilments, corresponding to the distinction between the two types of action proposed by Kirsh and Maglio and others, as shown in the two linkographic representations on the left of Figure 4.

However, we also observe episodes that start with pragmatic objectives and end with epistemic fulfilments, and vice versa (see the two diagrams at the centre of Figure 4). In these instances, epistemic objectives lead to pragmatic fulfilments, or pragmatic objectives lead to epistemic fulfilments. On some occasions, moreover, episodes turn out to be dead-ends ("This doesn't work. Let's see if there are better ways forward."), visualised with the + symbol in the two diagrams on the right of Figure 4. The design episodes we analysed thus fall into a total of six different categories of episodes starting with pragmatic or epistemic objectives and ending with pragmatic or epistemic fulfilments or dead-ends. These observations put the mutually-exclusive distinction between the two kinds of action into question – at least as far as design processes are concerned. Moreover, we identify numerous design episodes as falling into one of these six categories within a given time frame and parts of such episodes that fall into other categories when interpreted across shorter or longer time frames.

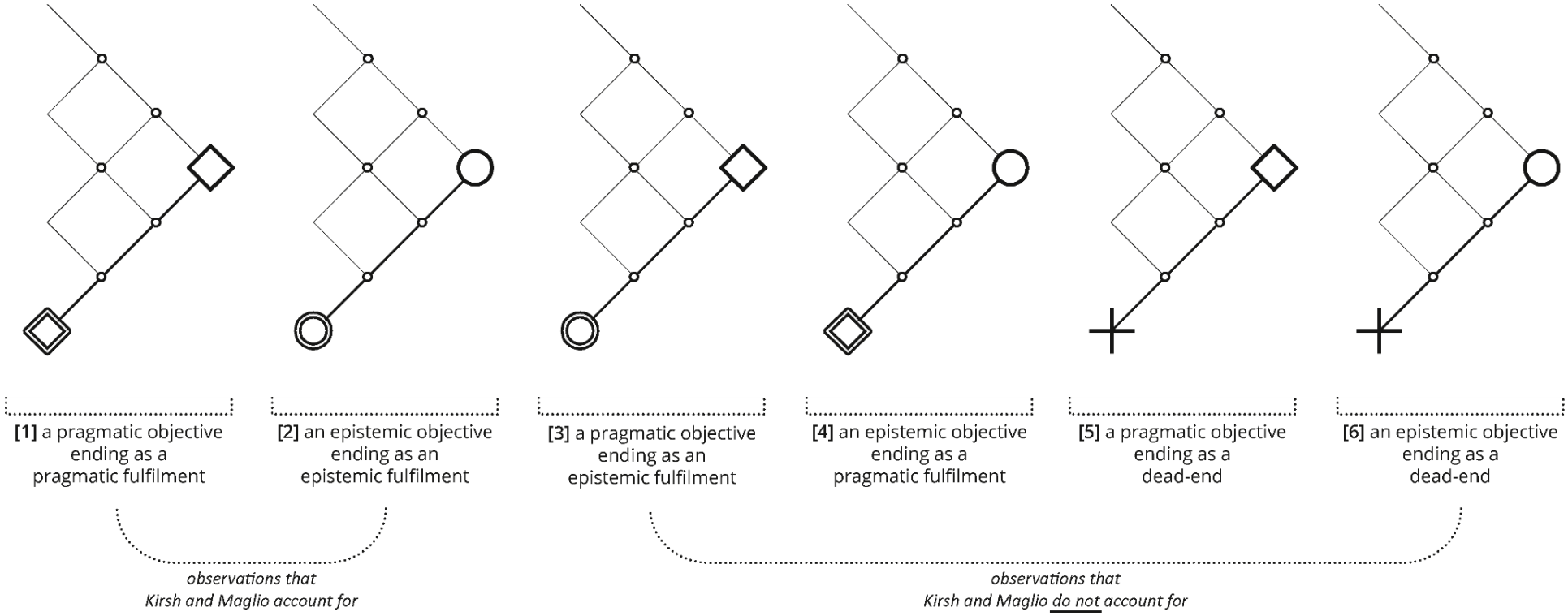


Figure 4. Observation of six different kinds of episodes.

These preliminary findings are, to some extent, in accord with Kirsh and Maglio's distinction between pragmatic and epistemic actions, reaffirming the distinction's value in the critique of linear planning models and offering some terminological differentiation to describe design action beyond linear purposefulness. Building upon the circularity emphasised by Kirsh and Maglio, however, our findings also show that further differentiation of analytical and descriptive categories is necessary for the context of design. To address this necessity, we propose six analytical and descriptive categories of design episodes, relating the setting of epistemic or pragmatic objectives to fulfilments with epistemic or pragmatic yields or dead-ends to investigate design processes. In so doing, we propose an extension of Kirsh and Maglio's theory of purposeful human action, hoping to inform design theoreticians and practitioners of the interplay between the two kinds of action in contexts characterised by ill-defined and open-ended goals.

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