1 Johanne Stege Bjørndahl*, Riccardo Fusaroli, Svend Østergaard
2 and Kristian Tylén

3 **Thinking together with material** 4 **representations: Joint epistemic actions** 5 **in creative problem solving**

9 **Abstract:** How do material representations such as models, diagrams, and draw-
10 ings come to shape and aid collective, epistemic processes? This study investi-
11 gated how groups of participants spontaneously recruited material objects (in
12 this case, LEGO blocks) to support collective creative processes in the context
13 of an experiment. Qualitative microanalyses of the group interactions motivate
14 a taxonomy of different roles that the material representations play in the joint
15 epistemic processes: *illustration*, *elaboration*, and *exploration*. Firstly, the LEGO
16 blocks were used to illustrate already well-formed ideas in support of commu-
17 nication and epistemic alignment. Furthermore, the material concretization of
18 otherwise abstract ideas in LEGO blocks gave rise to elaboration: discussions,
19 requests for clarification, and discovery of unnoticed conceptual disagreements.
20 Lastly, the LEGO blocks were used for exploration. That is, the material represen-
21 tations were experimented on and physical attributes were explored resulting in
22 discoveries of new meaning potentials and creative solutions. We discuss these
23 different ways in which material representations do their work in collective rea-
24 soning processes in relation to ideas about top-down and bottom-up cognitive
25 processes and division of cognitive labor.

27 **Keywords:** epistemic action, extended mind, distributed cognition, joint problem
28 solving, collective reasoning

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34 ***Corresponding author: Johanne Stege Bjørndahl:** Center for Semiotics, Department for
35 Aesthetics and Communication, Aarhus University, Denmark. E-mail: jo.bjorndahl@gmail.com
36 **Riccardo Fusaroli:** Center for Semiotics, Department for Aesthetics and Communication; and
37 The Interacting Minds Center, Department of Culture and Society, Aarhus University, Denmark
38 **Svend Østergaard:** Center for Semiotics, Department for Aesthetics and Communication,
39 Aarhus University, Denmark
40 **Kristian Tylén:** Center for Semiotics, Department for Aesthetics and Communication; and The
Interacting Minds Center, Department of Culture and Society, Aarhus University, Denmark

1 Introduction

In a great variety of everyday situations, people recruit and manipulate representational artifacts to aid their cognitive processes. We write down things to remember, make maps to assist spatial navigation, and organize our workspace to simplify procedures and aid decision-making (Hutchins 1995a). While a simple household budget would be a daunting task to design and maintain in our heads, pen, paper, and a calculator can make it trivial. Crucially, many of these and other artifacts serve the purpose of facilitating joint reasoning processes and problem solving. Collaborative brainstorming, problem solving, and decision-making are part of many people's daily life and in these contexts, the creation of material representations such as drawings, diagrams, and models is a powerful tool for sharing, refining, and discussing perspectives. They create a 'public' structure open for negotiation and joint manipulation. Representational models thus facilitate collective thought processes by externalizing ideas and thoughts into public space (Clark & Chalmers 1998). This gives them a "manipulable" format that affords different kinds of testing, exploration and reorganization of semantic elements, which in turn can give rise to new insights and ideas.

In this paper, we advance a taxonomy of the ways material representations are developed and engaged to facilitate collective thinking. The taxonomy is developed on an empirical video corpus of groups of 4–5 participants solving a series of creative workshop tasks together. Based on qualitative microanalyses of the interactions, we identify and discuss different distinctive roles that the representational models come to play in the joint epistemic actions taking place in the group interactions. At the same time, the taxonomy is intended as a first step towards a more general understanding of joint epistemic actions across contexts.

1.1 Objects as tools for thought

According to traditional views in cognitive science, cognitive processes take place exclusively inside the head, provided input from and producing output onto the world. However, during the last couple of decades, theories and studies of human cognition have discussed how cognitive processes can be claimed to extend into the environment through manipulation of and interaction with objects (Clark 2008; Roepstorff 2008). In their seminal article, Clark and Chalmers formulate it thus: "If, as we confront some task, a part of the world functions as a process which, were it done in the head, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world is (so we claim) part of the cognitive process." (Clark & Chalmers 1998:4)

1 A central concept in this active externalist approach to cognition is that of
2 *epistemic actions* (Kirsh & Maglio 1994). While *pragmatic actions* have the pur-
3 pose of changing the environment so to directly achieve an instrumental goal,
4 *epistemic actions* are those actions that change the environment for the purpose
5 of aiding a cognitive process. In the game of Tetris, players have to make quick
6 decisions on how to rotate a 'zoid' (shape) in order to make it fit a socket. Contrary
7 to intuition, Kirsh and Maglio found that expert players fiddle more, performing
8 a higher number of manual (rather than mental) rotations than novices. While
9 mental rotation is a relatively slow and cognitively costly process (Shepard &
10 Metzler, 1971), manual rotation was shown to be a faster and more effective way
11 to explore possibilities and inform decisions in regard to the final placement of
12 the Tetris zoids.

13 Along similar lines, in a study of Scrabble, participants were found to in-
14 crease performance (produce more words) when allowed to manually manipu-
15 late letter tiles (Maglio et al. 1999). Other findings include Vallée-Tourangeau &
16 Krüsi Penney (2005) showing how performance in traditional problem solving
17 paradigms increased if participants were allowed to manipulate the material rep-
18 resentations in the task. Together, these studies point to the existence and per-
19 vasiveness of epistemic actions: the manual manipulation of external, material
20 representations in order to facilitate cognitive processes, *de facto* embodying part
21 of the computational process.

22

23

24 1.2 Thinking together

25

26 While the previous examples highlight cases where individual cognitive pro-
27 cesses extend into the immediate material environment, a crucial and perhaps
28 under-investigated aspect of extended cognition is the role of social distribution
29 of cognitive processes in contexts of interaction (with a few important exceptions,
30 cf. Hutchins 2011). Recent studies on collective problem solving point to ways
31 in which social interaction can change and enhance performance on cognitive
32 tasks (Fusaroli et al. 2013). A study by Bahrami and colleagues (2010) showed
33 that when pairs of participants were allowed to interact and discuss freely while
34 doing a simple visual task, they performed significantly better than the best of the
35 individuals solving the task alone. A follow-up study compared well- and poorly
36 performing pairs and established that pairs that managed to jointly carve linguis-
37 tic tools that optimally met the affordances of the task would gain greater perfor-
38 mance (Fusaroli et al. 2012).

39 Likewise, studies in the field of cognitive anthropology and ethnography
40 emphasize socially distributed aspects of cognition: e.g. in the distribution of

perceptual, reasoning and decision-making processes across the crew and material environment in contexts of navigating warships or controlling airplane cockpits (Hutchins 1995a; 1995b), as well as in archeological scientific practices and court room expert testimonials (Goodwin 1994). In all these cases, even basic perceptual actions are shown to be shaped, taught, and reshaped through the dynamics of social interactions. They are highly coordinated social practices where material artifacts are often engaged to structure the activity, establish and highlight shared reference points (Alac & Hutchins 2004; Goodwin 1994, 2000). More generally, the joint recruitment of material representations has been shown to aid the exchange of ideas, facilitate the acquisition and production of knowledge and assist people in externalizing and share parts of ideas that are not easily shared using language alone (Kirsh 2009, 2013).

1.3 The role of material representations in collective, creative processes

The studies cited above put an emphasis on cultural artifacts used in highly scripted and specialized practices (from the game of Scrabble to the navigation of warships and planes, archeological work, etc.). In these contexts, artifacts are carefully designed to aid specific cognitive tasks, and thus might be argued to constitute a distinct category of “cognitive artifacts” (also including objects such as maps, rulers, dictionaries, etc, cf. Heersmink 2013). But what about everyday practices in which more generic materials and objects are coopted for unforeseen cognitive needs (Perry 2013)? In this study we proceed to investigate how objects without an obvious normative or canonical cognitive function are spontaneously recruited to do cognitive work in the context of a creative and open-ended collective activity. In other words, groups of participants had to solve joint open-ended creative tasks relying on LEGO blocks.¹ LEGO blocks are characterized by an almost unlimited number of possible combinations (Abrahamsen & Eilers 2007). They have physical features such as colors and some have figurative content resembling people, hats, trees and cogwheels, etc. LEGO is usually used to build models of real world things, such as ships, houses, or animals. Thus, the figurative properties of the LEGO blocks provide a potential for assigning meaning and possibly enacting scenarios and narratives. In this paper we present some of the ways in which these properties were spontaneously recruited to support

¹ In principle it could have been any set of objects without precedence for employment in cognitive tasks. We thus suspect our finding to generalize beyond the case of LEGO.

1 communication, coordination, and joint reasoning processes in unconstrained
2 interactions in groups of several people solving a creative task together.

3 4 5 **2 Building representational models together** 6 7 **– a creative workshop task**

8 The interactions took place in groups of 4–5 participants solving an open-ended
9 creative group task as part of a two-day psychology experiment. The task was
10 to jointly build LEGO models demonstrating the group's shared understanding
11 of abstract concepts such as "Justice," "Security," and "Collaboration." Abstract
12 concepts were chosen because on the one hand, they are common in everyday
13 discourse, while on the other they present themselves as particularly challenging
14 to define and instantiate. We thus expected them to effectively stimulate group
15 discussions and elicit creative solutions. The task was inspired by the workshop
16 method LEGO Serious Play (Gauntlett 2007), widely employed to facilitate con-
17 structive discussions and the sharing of ideas.

18 The groups were instructed to complete the construction within 5 minutes,
19 during which they could freely use the blocks in any way they wanted. They were
20 explicitly told that there was not a single fixed solution to the task and that after
21 the trial, one of the members of the group would present the model to the ex-
22 perimenter. The interactions and communication within the groups were other-
23 wise unconstrained. The LEGO materials consisted of standard Lego Serious Play
24 starter kits: approximately 50 blocks, including a wide variety of LEGOs, such as
25 cogwheels, tubes, strings, trees, flowers, windows, wheels, and a LEGO man and
26 girl (see Figure 1). Participants had all basic knowledge of LEGOs and assembling
27 techniques.

28 The study involved observation of the group sessions combined with qualita-
29 tive video analysis of approximately 20 hours of video recordings from the exper-
30 iment. A first screening of the videos motivated a number of broad categories of
31 how LEGO blocks were used in negotiations of conceptual understanding of the
32 abstract concepts and planning of the resulting models. Further video analysis
33 informed a taxonomy of procedures and motivated the selection of shorter epi-
34 sodes for microanalysis. The examples presented in the following were selected
35 as representative cases from the collection of examples relating to three identified
36 types of joint epistemic actions. The groups presented high variability in their
37 reliance on any of these strategies.

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Fig. 1: LEGO Serious Play Set

2.1 Building blocks for sharing ideas

In the experimental sessions, the LEGO blocks were employed for quite varied functions. They were obviously the material out of which a model – the solution to the task – was to be built and therefore routinely assigned meaning and assembled in signs and scenarios of different sorts – e.g. a house or a person driving a car. Beside this instrumental outcome, the participants made an active use of the blocks during the planning phase to enable more effective and nuanced communication and joint epistemic processes.

Through observation and video analysis, we identified three main functions of LEGO blocks in enabling and supporting joint reasoning: illustration, elaboration, and exploration.

In ‘Illustration,’ LEGO blocks are recruited to support the communication of already well-formed ideas. Blocks are thus primarily engaged in a ‘top-down’ way for purposes of reaching epistemic alignment (mutual understanding).

In ‘Elaboration,’ the concrete instantiation of an already agreed upon idea in LEGO blocks comes to reveal unnoticed conceptual aspects and disagreements thus leading to collective examination, discussion, and clarification. Although the original idea is not challenged or changed, the material representation motivates perspectives and dimensions in a more bottom-up manner that would otherwise have escaped attention.

In ‘Exploration,’ participants critically rely on the manual manipulation of representational materials to generate ideas. In these cases, the LEGO blocks are

1 experimented on and explored, resulting in the discovering new innovative ideas,
2 practices, and meaning potentials. This can be regarded more of a bottom-up type
3 of process than Elaboration as the manual manipulation of the materials is given
4 an active role in shaping and catalyzing the joint epistemic processes.

5 The three types of object manipulation can be considered as representing
6 regions in the continuous spectrum of joint epistemic actions, where the objects
7 involved play an increasingly active role in the collective cognitive processes. The
8 conceptual distinctions and differences between the three types will be further
9 elaborated in the discussion with special regard to the role of distribution of cog-
10 nitive labor.

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13 **2.2 “Then he can’t do like this” – Illustrating what I am saying**

14

15 Properties of a shared material environment can be recruited to establish ma-
16 terial referents that aid communication and understanding. In this first exam-
17 ple, we show how communicative topics that are difficult to convey verbally can
18 become easier to comprehend with the aid of physical referents established in the
19 here-and-now communicative act. Thus, we show how LEGO blocks were sponta-
20 neously recruited in the role of stable material referents for communicative con-
21 tent in order to aid communication and understanding between participants in
22 a group.

23 The following exchange is taking place in a group of five participants who
24 were given the task of building a model of their understanding of the concept
25 “Collaboration.” Prior to the episode below, Marvin (see Figure 2 below) had been
26 presenting an idea for the model to the other participants, but they expressed
27 difficulties understanding it. Encouraged by Steven, Marvin gathered a few LEGO
28 blocks, and put them together in a small structure, while the others talked about
29 other possible ideas on how to solve the task.

30 Just before the exchange below, Marvin initiated a repetition of the scenario,
31 now using the selected LEGO blocks. As seen in Figure 2, Marvin got the attention
32 of the other participants who then focused on the LEGO blocks in his hands. The
33 other participants thus acted as recipients of his speech and actions throughout
34 the exchange.

35 In the exchange, Marvin first established the referents to be used in the enact-
36 ment of the scenario; the LEGO man by means of holding it in his hand and the
37 food by means of pointing to an empty location and telling the others (to imagine)
38 that it was there. The formulation “then he can do like this” (line 4) is typical for
39 this type of illustrative epistemic acts in that the deictic element ‘this’ transfers
40 the attention from the verbal production to the visually accessible manipulation

Fig. 2

(1) Excerpt 1²

1 Marvin *Let's say the food is here [(,.75 sec)]
2 *Is holding a LEGO man in one hand [taps with the other
3 hand where the hypothetical food is to be imagined] →
4 Then he can't do like this
5 [(1.5 sec) Because then the string comes off]
6 [does a slow pulling motion with the LEGO man
7 until the string comes off]* →
8 (1 sec)
9 Steven Hmm ± ((falling intonation))
10 (1.5 sec)
11 Marvin [Looks at Steven] →
12 Steven Isn't that the ((continues))

2 In the notation used, speech is represented in roman script and gestures in italics. Gestures and words that co-occur temporally are marked with paired brackets, and paired asterisks show where series of gestures begin and end. Descriptive comments that are not part of the transcribed interaction are in double parenthesis. All participants are anonymized.

1 of the external objects. Thus, the following verbal production “Because then the
2 string comes off” (line 5) is now working in parallel with the physical manipula-
3 tion of the LEGO bricks. In lines 9–12, Steven’s response showed that he under-
4 stood the scenario, and he carried on talking about it followed by acknowledge-
5 ments from the others in the group.

6 Relying on a combination of material objects and gestures, Marvin got his
7 point across. The scenario he had described was so complicated that it was hard to
8 convey with words and gestures only. The communicative act he therefore carried
9 out in this exchange had two parts: one establishing the LEGO blocks as physi-
10 cal, visually stable referents and another enacting the scenario using these refer-
11 ents. Although other suggestions for models were presented, in the end, Marvin’s
12 model became the foundation for the final result of the collective task (see Figure 3).

40 Fig. 3

The example shows how the LEGO blocks were not only used to solve the task in the trivial sense, that is, as materials for building a model of “Collaboration.” More than that, they were used in the initial negotiation and planning to aid the communication of an idea that was difficult to convey. However, the idea originated previous to the actual manipulation and the LEGO blocks were merely used to illustrate it. However, in the following examples, properties of the material environment give rise to discussions that feed back into and modify the original idea, thus more deeply influencing and shaping the epistemic processes in the participants’ problem solving.

2.3 “He is power” – Elaborating on your ideas

Sometimes the manipulation of the physical properties of a representational artifact can affect and even stimulate joint epistemic processes. This happens when concrete physical attributes of the materials motivate group discussions and further new perspectives. In the following example, the selection of hats in the set of LEGO blocks available to the participants influenced how a figure in the model was represented, leading to discussion, change, and elaboration of the conceptual representation of the target concept.

This exchange took place in a group of five jointly building a model of the concept “Justice.” At the point where the exchange took place, they had already built a scale-like structure and a LEGO man representing “the law.” Leading up to the exchange, Sarah and Mary (see Figure 4) were discussing the LEGO man representing “the law.” Sarah was holding the LEGO man with both hands and had just been pointing to different parts of it. She had previously assembled the LEGO man, giving him a sword and a crown. So far, the crown was never explicitly mentioned.

By mentioning the crown, Simon directed attention to part of the model that had not previously been discussed. Furthermore, by using “But” and a question form, he showed that he wanted Sarah to explain more about that part of the figure and that he did not have a positive attitude towards it. Sarah initiated a response, but then hesitated and stalled (line 3), which led Mary to jump in with a suggestion for the motivation of the crown: the LEGO-man wears it because “He is power” (line 6). Simon acted as the primary addressee and in line 9 he signaled that he received their explanation, but was not completely satisfied, by starting with “But it’s just that . . .” From here, the group started a further discussion about crowns, justice and power, going on for more than a minute. Finally the group agreed on changing the crown for a black hat (see Figure 5 below).

Fig. 4

(2) Excerpt 2

- 1 Simon *But the law he's wearing a crown or what?
2 Sarah *Is holding the LEGO man wearing a crown with both hands
3 Sarah Yes but [that's-that's just] [because he's
4 [moves her right hand away and
5 [grabs the crown on the figure]*
6 Mary He is power]* ((low voice))
7 Sarah *[,h yeah]* ((spoken during inhalation))
8 *[,h yeah]* ((spoken during inhalation))
9 Simon But it's just that in general ((continues))

Fig. 5

Prior to the exchange, when Sarah assembled the LEGO man representing “the law,” she had to choose amongst the parts available to her (a finite set of LEGO blocks), some of them carrying little symbolic meaning and others, such as the crown, carrying cultural, symbolic, and historic references. By assembling a crowned LEGO figure, Sarah made a choice between the different possibilities available to her, and concretized a part of the conceptual representation not readily implied by the abstract verbal label “the law.” The process of representing the verbally shared conceptual content using concrete material objects made it suddenly clear for Simon that Sarah conceived of the model in a way that he did not agree with. In other words, the material concretization in this case gave them an opportunity to discover that they were not aligned in their conception of “Justice.” In this way, the crown motivated a discussion of the attribution of

1 power as a topic relating to Justice, which was not part of any of the previous
2 ideas and concepts introduced by the participants in the group.

3 The example shows how material objects, such as LEGO blocks, can give rise
4 to the actualization of ideas otherwise not in the attention of the participants
5 prior to the task. Had there been no crown in the collection of LEGO blocks,
6 no one would have missed it, but because it was present the relation between
7 authority and justice was actualized. It might even be that it was Sara moving
8 the LEGO man around that brought Simon's attention to the crown, similar to the
9 Tetris player's manipulation of the zoids bringing new potential fits to attention.
10 In any case, the material concretization of the original idea gave rise to the discov-
11 ery of discrepancies in the mental representations held by different participant,
12 leading to discussions and development of conceptual agreement. In the exam-
13 ple, we see how material objects, due to their concrete features such as colors,
14 shapes, and even symbolic references, motivate (or even force) the elaboration of
15 otherwise abstract and fuzzy concepts.

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18 **2.4 “She has to be moving fast” – Exploring materials** 19 **together**

20

21 The previous example of elaboration shows how the particular material medium
22 itself gives rise to ideas, which would have not otherwise been connected with
23 the concept the participants are supposed to build. It illustrates how the concep-
24 tual representation is discussed, elaborated, and changed at least partly due to
25 the particular materials available in the LEGO set. In the following example, the
26 collective manipulation of LEGO blocks is shaping the way a group conceptu-
27 alizes and constructs the target concept to an even higher extent. The example
28 shows a group testing and exploring the shared materials together in order to
29 seek out perspectives and solutions and generate ideas. This gives rise to a more
30 bottom-up driven approach: greater responsibility is allocated to the shared ma-
31 terial environment in motivating the conceptual frame and thereby the solution
32 to the task.

33 The exchange took place in a group consisting of four people. They were
34 given the task to build a collective model of the concept “Collaboration.” Rather
35 than starting out by verbally negotiating their joint understanding of the concept
36 as it had happened in many other group sessions, the participants started out
37 by choosing and assembling some smaller parts from the LEGO pile that they
38 wanted to include in the overall model. They agreed on using a LEGO “boy,” a
39 LEGO “girl,” and a foundation on which to place them. Previously in the inter-
40 action, Louise (see Figure 6 below) had assembled the LEGO girl but had not been

Fig. 6

(3) Excerpt 3

- 1 Christian *[She has to be][moving fast if she is to stay][standing]*
 2 Louise *[Reaches towards the guys with the figure in her hand]
 3 [slides the figure back and forth in front of them] →
 4 [retracts, still holding the LEGO girl figure]*
 5 Michael h.haha yeah
 6 (1.5 sec)
 7 Michael But it could have something to do with cooperation *[that]
 8 *[Pics up the LEGO man with one hand]
 9 [he has to help her
 10 [turns it between his fingers]
 11 Then he could be][standing][an:d uh
 12 [points with it's legs at the LEGO girl in Louise's hands]
 13 [turns the figure between his fingers again] →
 14 Christian Arh, well now it's all coming][together]* ((continues))
 15 Michael [lets the LEGO man go]*

1 able to find the legs, having long searched for them in the pile. Michael and Chris-
2 tian suggested an alternative: the LEGO girl got a pair of wheels instead of legs.
3 Michael and Christian had also been working on the foundation for the model,
4 decorating it with cogwheels. Leading to the exchange, Louise tried to place the
5 LEGO girl on the table a couple of times, but it kept falling down as the wheels
6 would not afford a standing position. At first the testing was “private,” close to
7 Louise, while the others were talking about something else.

8 Interestingly, in the initial phase of the session, the group had not formed any
9 overall idea or narrative binding together their different parts of the model. How-
10 ever, Louise’s mechanical action of sliding the figure back and forth motivated
11 Michael’s idea that the LEGO man could help her. At the same time this became
12 a way to integrate otherwise incoherent and scattered individual elements into a

Fig. 7

No text
callout
until
Section
3.1?

coherent conceptual scenario. Contrary to the Tetris game, the two components of the epistemic action – mechanical and epistemic – were distributed between different participants in a collective task: while Louise manipulated the blocks (lines 2–4), it was Michael who drew the cognitive consequences of the manipulation (lines 7–13).

The example illustrates how the LEGO blocks are recruited, explored, and experimented on to actively generate new ideas, rather than simply present or illustrate already well-formed ideas. It is a collective problem-solving process that takes more of a bottom-up approach to the representational structures, letting the manipulation, exploration, and discoveries in the provided materials perform part of the conceptualization process.

3 Discussion

When thinking together, people are often observed to spontaneously employ and manipulate material representations. In this paper, we point to different ways in which people spontaneously engage objects in the context of a creative problem solving activity. Crucially, the artifacts used in the present study had not been designed by cultural or normative practices to be used in any of the interactional ways described here. We have presented very salient examples using crowns and wheels, but similar joint epistemic processes have been observed on less figurative elements, e.g. blocks of different colors supporting the “Justice” model helped the participants to express and discuss the relations between diversity, fairness, and justice. Thus, our observations point to a broad capacity to employ material objects in communication and collective reasoning processes that is not necessarily dependent on, although arguably fundamentally influenced by, the specific objects that are subject to the manipulation. In these activities the material environment is engaged in a way that feeds back into, changes and shapes the collective cognitive processes.

In our study, we identify three roles that material representations play in creative problem solving: i) In the process of supporting and illustrating the verbal communication of a complex scenario, the material objects were used as stable referents of significant elements available for enactment, ii) the concrete externalization of representational content in physical materials sometimes brought attention to details and provided opportunity for the participants to discover and explore their disagreements on central conceptual issues, and iii) explorative experimentation on the provided materials led to unanticipated discovery of new meaning potentials that critically motivated or changed the conceptualization of a concept.

3.1 Joint representational objects and the distribution of cognitive labor

Illustration, elaboration and exploration, are, however, not just distinctly different ways to involve objects in a collective creative task. The interactional types seem to constitute a continuum spanning from more top-down to bottom-up driven joint epistemic processes. The top-down processes being those where the materials are employed to support and enact already established and well-formed ideas, while the more bottom-up type processes are those where the manual manipulations of the material objects come to significantly feed back into and shape the joint epistemic process.

Furthermore, the different types of joint epistemic processes were characterized by different degrees of distributions of cognitive labor. The more top-down types of process, where objects were engaged to illustrate a well-formed proposition, were more or less carried out by a single participant. In contrast, the more bottom-up types that involved manual exploration of the materials involved a higher degree of distribution of cognitive labor between the involved participants. More specifically, in the example of illustration, the interactional construction of the conceptual representation mainly originated from a single person, Marvin, while other participants primarily carried the roles of addressees. The example is thus characterized by a largely unidirectional exchange of conceptual content; Marvin is presenting while the others are receiving and observing. Furthermore, by carrying out the illustration he accomplished more than making the others understand and receive his proposal; the enactment established a degree of authority over the building blocks. After presenting the idea, the blocks were easily transformed from being a tool for illustrating the idea into the foundation for the actual model constituting the solution to the collective task, thus overruling other competing conceptualizations presented in the group. The final model that the group produced in fact only featured one minor modification compared to Marvin's first proposal (Figure 3).

Turning to the second example, the elaboration, we observe a somewhat different structure in terms of social involvement. Parts of the conceptual model that were chosen by one person, were pointed out, questioned, and elaborated on by others in ways that fuelled a central discussion in the group. The elaborative manipulation involved three participants; Steven raised the topic that Sarah and Mary then cooperated on a response to. The exchange engaged the model in a way that led to a negotiation of conceptual structure and profoundly influenced the end result of the collaborative activity. The model ended up as a concatenation of ideas originating from multiple parties: Sarah came up with the idea of a person holding a stick representing "the long arm of the law" while Simon raised

the symbolic and cultural importance of what kind of headwear he is given and, 1
in the end, equipped the law with a black hat instead of a crown (Figure 5). In 2
this way, the semiotic structure was negotiated and distributed between multiple 3
participants motivating a higher degree of joint ownership. 4

In the third example, three participants (Christian, Louise, and Michael) co- 5
operated on constructing the conceptual structure that later became the foun- 6
dation for the collective model. First of all, Christian and Louise jointly brought 7
attention to the central mechanical problem: the actions that Louise was doing 8
with a figure closely matched different points in what Christian was saying. How- 9
ever, a third person, Michael, became the source of the solution. The process of 10
establishing a semiotic structure was distributed between all three participants, 11
each providing parts that were eventually combined into the resulting, coherent 12
narrative model (Figure 7). 13

Together, these observations point to a tendency for the more top-down ways 14
of engaging material representations to be supportive of gaining and maintain- 15
ing authority as well as to provide powerful tools for sharing conceptual repre- 16
sentations. In contrast, more bottom-up oriented approaches are characterized 17
by more distribution of cognitive labor, more unconventional usage of materials, 18
and more possibility for unanticipated insight and solutions as well as problems 19
and disagreements that shape the problem solving processes. Given the richness 20
of the materials, further studies are needed to investigate the relation between 21
the interactional dynamics of collective problem solving and the role of authority, 22
conflict, and alignment, as well as the role of more structured and rule-based 23
collaborative practices. 24

Many studies have shown how distributed cognitive processes unfold in 25
reliance on particular cognitive technologies and artifacts predesigned to do cog- 26
nitive work (Alac & Hutchins 2004; Goodwin 2007; Hutchins 1995a, 1995b). With 27
this study, we have extended the investigation of pragmatic and epistemic actions 28
and distributed cognition to the case of collective creative processes. Besides, in 29
this joint creative task, participants were left with ordinary LEGO blocks that do 30
not come with specific normative procedures or instructions in terms of how they 31
should be used for joint reasoning. This enabled us to observe how participants 32
would spontaneously engage the objects for epistemic purposes. They readily did 33
so for purposes of illustrating ideas, elaborating and concretizing details and ex- 34
ploring new meaning potentials. We suggest these categories form a more general 35
taxonomy of joint epistemic actions relating to a broad variety of everyday con- 36
texts. However, future studies relying also on un-elicited, naturalistic data are 37
warranted to further develop and verify this work. 38

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40

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Bionotes

Johanne S. Bjørndahl is a Ph.D. fellow at Center for Semiotics (Aarhus University). 16
She holds a BA in Linguistics and an elite MA in Cognitive Semiotics from Aarhus 17
University. Main research interests are within social cognition, interaction studies, 18
and the role of objects in human cognition, which she approaches from different 19
perspectives involving cognitive science, cognitive anthropology, semiotics, and 20
linguistics. She is currently involved in a research project called *Joint Diagram- 21
matical Reasoning in Language* funded by the Danish Council for Independent 22
Research - Humanities. 23
24

Riccardo Fusaroli is a postdoctoral fellow at the Center for Semiotics and Inter- 25
acting Minds Center, Aarhus University. He holds a Ph.D in Semiotics from the 26
University of Bologna. His research focuses on investigating social interactions 27
employing experimental setups and dynamical systems models. He has a partic- 28
ular interest in language as a complex adaptive system for social coordination, 29
experimental semiotics, and social impairment in neuro-psychiatric conditions. 30
31

Svend Østergård is a mathematician by training and a PhD in semiotics. He cur- 32
rently serves as an Associate Professor at the Center for Semiotics, Department 33
for Aesthetics and Communication, Aarhus University. His current research inter- 34
ests focus on dynamic models of social interaction and especially how language 35
structure emerges as a result of interaction. He has published a number of articles 36
on dynamic semiotics and the books *Mathematics of Meaning* (1997), about the 37
use of catastrophe theory and mathematics in the study of semantics, and *Kogni- 38
tion og katastrofer* (1998), about cognitive linguistics and its relation to the theory 39
of dynamic models. 40

1 *Kristian Tylén* has an educational background in cognitive semiotics (Aarhus
2 University) and linguistics (University of Southern Denmark) and currently holds
3 a position as a postdoctoral fellow at the Center for Semiotics and The Inter-
4 acting Minds Center, Aarhus University. His main research interests includes
5 social coordination, meaning-construction and the role of objects in human cog-
6 nition, which he approaches from a broad range of perspectives involving cog-
7 nitive science, neuroscience, semiotics, and linguistics. Together with professor
8 Frederik Stjernfelt (Copenhagen University), Kristian Tylén is currently coordinat-
9 ing a research project called *Joint Diagrammatical Reasoning in Language* funded
10 by the Danish Council for Independent Research - Humanities.

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