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EDITED BY
Stephanie M. Carlson,
University of Minnesota Twin Cities,
United States

REVIEWED BY
Sabine Doebel,
George Mason University, United States
Laura Franchin,
University of Trento, Italy

*CORRESPONDENCE
Michael Tomasello
✉ Michael.tomasello@duke.edu

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An agency-based model of executive and metacognitive regulation

Michael Tomasello[1,2]*

[1]Duke University, Durham, NC, United States, [2]Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

In the context of agentive decision making and action, both executive and metacognitive processes serve self-regulatory functions—just on different hierarchical tiers. In the agency-based model proposed here executive processes monitor and control action and attention from an executive tier of operation, and metacognitive processes monitor and control those executive processes from a second-order metacognitive tier of operation-both with the function of facilitating effective and efficient behavioral decisions. Each is best conceptualized as comprising three key components: (i) what is regulated, (ii) how, via what processes, is it regulated, and (iii) where, in what cognitive workspace, is it regulated—either in individual or in shared agencies. Developmentally, evidence is presented that executive processes for regulating both individual and joint agencies emerge only after 9–12 months of age, and metacognitive processes for regulating both individual and collective agencies emerge only after 3–4 years of age. Cognitive flexibility, as an important outcome, derives from the child's attempts to metacognitively regulate differing social perspectives within shared agencies.

KEYWORDS

executive function, self-regulation, metacognition, agency, decision making

Metacognition is often defined as "thinking about thinking." But why do children (or adults) think about thinking? What psychological function does it serve? Most fundamentally, metacognitive processes serve self-regulative functions monitoring and controlling ongoing cognitive processes as children attempt to solve problems, learn new skills, or achieve challenging goals. Indeed, a term often used in the education literature is "metacognitive regulation."

This self-regulation view of metacognition suggests that it is related to executive function. But there have been few systematic attempts to spell out this relation. Perhaps the most explicit attempt is by Roebers (2017), who claims that executive function and metacognition play quite similar roles in children's behavior and cognition: "Both are higher-order cognitive processes enabling an individual to operate flexibly and adapt efficiently to new and challenging tasks … [Both] similarly encompass dynamic and regulatory functions, which are utilized to optimize information processing of more elementary, first-order tasks" (p. 33). She argues that in the way they are studied in the current literature the two functions comprise different "sub-processes." Paraphrasing slightly to emphasize aspects relevant to the current account, for executive function she identifies such things as attention shifting, behavioral updating, and behavioral inhibition, and for metacognition she identifies cognitive monitoring and cognitive control.

My paraphrases (i.e., adding in explicit reference to "attention," "behavior," and "cognition") are meant to emphasize the proposal I will defend here, namely, that executive function comprises cognitive processes that regulate attention and action, whereas metacognition regulates these executive-level cognitive processes themselves. Both are regulatory processes but operating at different psychological levels.

In this essay, I outline a theoretical approach to executive and metacognitive processes within a theory of human agency and its self-regulation, including processes of shared agency involving cooperative/normative self-regulation. After explicating the evolutionary foundations of the model, I spell out some of its implications for how best to conceptualize executive and metacognitive processes in human ontogeny.

1 Types of human agency

Tomasello (2022, in press) proposes a theory of human agency, decision making, and action that incorporates executive and metacognitive processes as two types of self-regulation. Beginning with a control systems account of agentive action, executive processes monitor and control action and attention in goal pursuit on an executive tier of operation, and metacognitive processes monitor and control those executive processes on a second-order metacognitive tier of operation—both with the function of facilitating effective and efficient behavioral decision making.

Figure 1 graphically illustrates the basic model. Although I know of no existing models of executive function and metacognition that take precisely this two-tiered form, there are existing hierarchical models of executive processes in both the adult (e.g., Koechlin and Summerfield, 2007) and developmental (e.g., Zelazo, 2004, 2015) literatures that focus on different phenomena than the current model. In particular: (i) the main focus of Zelazo's model is on consciousness (whereas I do not mention it); (ii) the structure of his model is detailed information processing (which I do not discuss); and (iii) his focus is on the complexity of rules that children can formulate and follow in adult-structured tasks (whereas I do not focus on rules at all). Also in developmental psychology, Carlson (2023) has recently begun investigating "reflection" (presumably a metacognitive process) in the context of executive function and the effect that children's sense of agency has on their cognition and motivation, which also is not in my model.

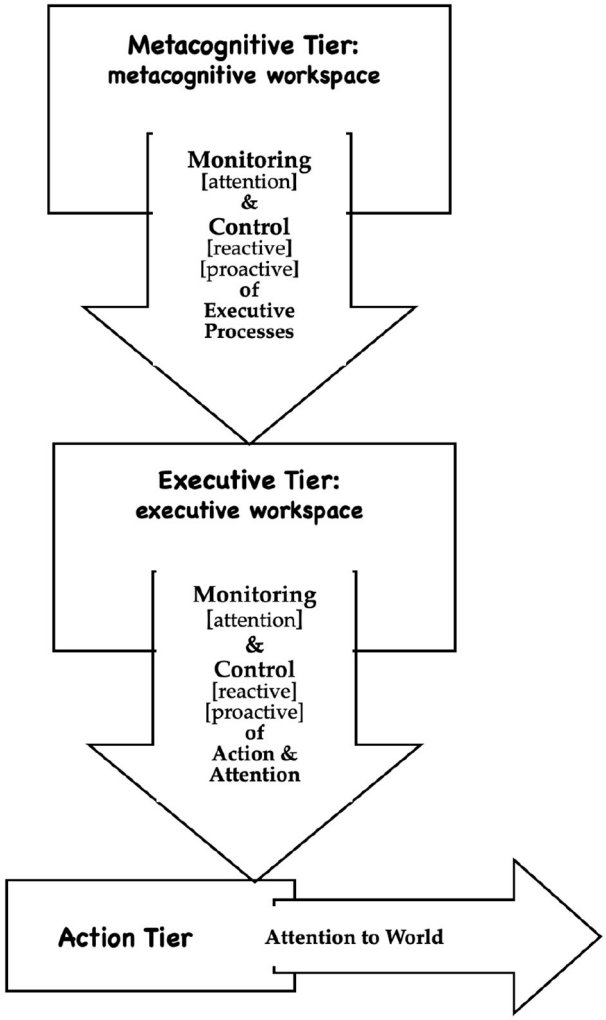

FIGURE 1
Graphic depiction of the hierarchical model of executive and metacognitive regulation.

1.1 Phylogeny

Tomasello (2022) proposes an account of how this human psychological architecture built up over evolutionary time. The model begins with the basic premise that cognitive processes evolved to facilitate agentive decision making and action. Not all organisms operate with cognitive processes, but rather their behavior is reflexive or stimulus driven because natural selection can anticipate the predictable arrival of particular stimuli and needed responses (examples in humans are breathing and swallowing). But in situations of unpredictability and uncertainty, what has evolved is an architecture of agentive decision making in which the individual perceptually and cognitively assesses the situation and makes a decision about what it can do to best pursue its goals. The computational model for agency is cybernetic control systems such as thermostats and self-driving cars that pursue and maintain reference values in dynamically changing circumstances.

If we focus on the species forming an evolutionarily line to humans, there have been three basic forms of individual agentive organization.

- **Goal-directed agency** evolved in the first vertebrates. This architecture is a simple control system sufficient for the organism to make a go/no-go decision (action tier only in Figure 1). These creatures were restricted to this mode of decision making because they had no executive tier of proactive executive control (although they were capable of a simple process of global reactive inhibition or "freeze" response).
- **Intentional agency** evolved in the first mammals. This architecture is a control system supervised by an executive

tier of functioning (executive and action tiers in Figure 1) with skills of thinking and planning sufficient for making an either/or decision between cognitively represented possibilities. These new types of decisions required proactive types of inhibitory control (e.g., suppression of unchosen behavioral options before acting) and executive coordination of attention.

- **Metacognitive (or rational) agency** evolved in the first great apes. This architecture is a control system supervised by an executive tier of functioning supervised by a metacognitive tier of functioning (metacognitive, executive, and action tiers in Figure 1) sufficient for reflecting on decisions already made and assessing their appropriateness given new information. These new types of decisions required metacognitive monitoring and control of executive decision making and metacognitive coordination of thinking and planning.

This hypothesized evolutionary trajectory reflects a natural buildup in complexity over evolutionary time, a common occurrence in biological systems of all types in which subsequent forms build on already existing forms (Bonner, 1988).

In addition, early humans also evolved some species-unique forms of shared agency based on cooperative goal pursuit and cooperative self-regulation, as they evolved more cooperative and cultural lifeways.

- Shared agency evolved in the early humans, who collaborated with others to make shared decisions in pursuit of shared goals. To do this they needed to coordinate with an individual partner (in a joint agency) or with the cultural group at large in terms of its conventions and norms (in a collective agency) and to collaboratively self-regulate these agencies normatively.

Evidence for this overall account comes from a wealth of behavioral experiments with contemporary model species: lizards as exemplars of the first land vertebrates acting as goal-directed agents; squirrels as exemplars of the first mammals acting as intentional agents; and chimpanzees as exemplars of the first great apes acting as metacognitive agents. The two forms of shared agency are connected to two early hominin species: *Homo heidelbergensis* as exemplars of the first joint agents, and *Homo sapiens sapiens* as exemplars of the first collective agents. The hypothesis is that there was a gradual transition from one form of agency to another across species in a perfectly normal process of evolution by means of natural selection.

1.2 Ontogeny

Tomasello (in press) argues that these same basic architectures structure children's cognitive development today, that they emerge at predictable ages, and that they both empower and constrain children's learning at particular ages. They emerge normally along the following general timeline.

- **Goal-directed agency** emerges in early infancy and operates throughout the first 9 months of life. Infants make only go/no-go decisions and operate with no executive processes other than a kind of global inhibition enabling them to freeze whatever they are doing and move on to another go/no-go decision.
- **Both intentional agency and joint agency** emerge at 9 to 12 months of age and predominate in toddlerhood until about 3 to 4 years of age. Toddlers make either/or decisions made possible by the emergence of an executive tier on which the toddler cognitively simulates possible actions and their likely results, regulating her attention and action via proactive thinking and planning. Toddlers also participate in joint agencies coordinating attentional perspectives and actions with others.
- **Both metacognitive agency and collective agency** emerge at 3 to 4 years of age and predominate in early childhood until about 6 years of age. Preschool youngsters make reflective decisions made possible by the emergence of a metacognitive tier on which the child regulates her executive-tier thinking and planning metacognitively. Preschool youngsters also coordinate their thinking, decision making, and perspectives metacognitively with peers in both joint and collective agencies.

The hypothesis is thus that there are qualitative shifts at 9–12 months and at 3–4 years of age in processes of psychological self-regulation. Specifically, from 9 months to 3 years of age children begin to executively regulate their actions and attentional perspectives proactively via thinking and planning—as well as those of partners in joint agencies. From 3 years of age onward children begin to metacognitively regulate their executive-tier thinking and planning via the coordination of conceptual perspectives—as well as normatively regulating others' and their own thinking and conceptual perspectives in both joint and collective agencies.

1.3 Novel features of the model

It is challenging to relate this agency-based model to the developmental literature on executive function and metacognition. The problem is that developmental psychologists have studied a variety of specific processes under these names, but these are typically defined in fairly narrow research contexts, leading to a proliferation of theoretical constructs. Thus, as the broader term, executive function includes such things as behavioral inhibition, cognitive inhibition, inhibitory control, self-control, effortful control, proactive executive function, continuous monitoring, working memory, self-regulation, emotion regulation, attentional control, attention shifting, attention regulation, cognitive flexibility, set shifting, task switching, and others. Although there is no consensus in the field, a widely used typology is that of Diamond (2013), who differentiates: (i) Inhibition (e.g., inhibitory control, self-control, behavioral inhibition, emotion regulation, etc.); (ii) Working Memory (i.e., holding information in mind and mentally working with it in various ways); and (iii) Cognitive Flexibility (e.g., attention shifting, set shifting, mental flexibility,

etc.). This typology has proven useful in identifying individual differences in developmental outcomes such as school achievement and emotional adjustment. But many researchers have bemoaned the plethora of terminological jargon in the field, and some have doubted the psychological reality of this menagerie of constructs (e.g., Doebel, 2020).

The main issue is that the types in Diamond's typology are very diverse: "inhibition" is a basic psychological process, "working memory" is a cognitive workspace within which processes operate, and "cognitive flexibility" is a trait that people or processes possess. In contrast, in the current model executive and metacognitive processes are not just a collection of independent mechanisms; they each play a distinct role in a regulatory system evolved to monitor and control agentive decision making and action. We may thus rework Diamond's tripartite typology in the context of the current model in the following way. First, "working memory" is an attentional workspace, and there are two types: one is an executive workspace (on the executive tier in Figure 1) that monitors and controls action and attention, and the other is a metacognitive workspace (the metacognitive tier in Figure 1) that monitors and controls these executive processes.[1] Second, inhibition is one of the main regulatory processes that takes place in these workspaces. But there are others, in particular processes that are more proactive such as planning and the coordination of thoughts and perspectives. Indeed, there can even be reactive and proactive processes of inhibitory control. Therefore, such things as "inhibition" and "cognitive coordination" in Diamond's typology may be recast as the actual regulatory processes by means of which agents monitor and control their decision making, processes such as thinking, planning, inhibitory control, coordination of thoughts, etc. Third, in this context, I would like to make a novel proposal—to be fleshed out in the next section that what Diamond and others call "cognitive flexibility" is about the coordination of perspectives, and this arises mostly in shared agencies in which individuals monitor and control one another's actions, attention, and perspectives. This interactive process is then internalized such that the individual can coordinate perspectives on things flexibly on her own.

To assess this model, in the coming section I empirically evaluate two hypotheses: (1) the hypothesis that there are systematic age-related changes in the organization of agency and decision making that structure the regulatory processes involved: first the executive regulation of attention and action beginning at around 9 to 12 months of age and then the metacognitive regulation of thinking and decision making beginning at 3 to 4 years of age; (2) the hypothesis that important aspects—indeed most of the species-unique aspects of children's cognitive flexibility arise initially from their participation in shared agencies in which they must coordinate their own actions, attention, perspectives, and decision making with those of a partner or a group with whom they are acting interdependently.

1 One could potentially posit emotion as something else to be regulated on the basic tier of action and attention. But what one is monitoring and controlling in such cases is less the involuntary emotions themselves and more their behavioral expressions and/or their effects on one 's actions.

2 The ontogeny of human agency, decision making, and self-regulation

Most research on children's executive function and metacognition uses standardized tasks—often asking children to follow adult-specified rules and focuses on individual differences in children's performance. My focus here, in contrast, is on the kinds of spontaneous self-regulation that characterize all of children's agentive decision making and action throughout their daily lives.

The proposal is that how children make decisions and regulate them depends on the cognitive architecture within which they are working, which includes one or another type of cognitive representation and self-regulative workspace. Further, self-regulation can be more reactive (e.g., inhibiting ongoing action or cognition) or more proactive (e.g., planning and coordinating action and cognition before acting). Finally, shared agency requires flexible interpersonal coordination—sometimes even shared decision making and collaborative and/or normative self-regulation. My focus in this section is on how these things all work together in the agentive decision making and self-regulation of, in turn, young infants (0 to 9 months), toddlers (9 months to 3 years), and preschoolers (3 to 6 years).

2.1 Young infants as goal-directed agents

The capacity for goal-directed action requires young infants (below 9 months) to make decisions about whether or not to execute an action in a particular situation, that is, go/no-go decisions. Despite appearances, they are not making either/or decisions about which action to perform. Thus, at first blush, it would seem that infants do make either/or choices between alternatives. For example, Hamlin et al. (2007) presented 6-month-old infants with two stuffed animals, one of which had behaved more nicely than the other. Infants tended to touch or grab the nice animal, which could be taken as evidence of an either/or decision between the two options. But it is also possible that in their initial observation of the animals' behavior infants developed an attraction to the nicer animal, and as soon as they saw it, they went for it without comparing the relative values of the two different options. Under this interpretation, they are making a go/no-go decision for an attractor, not an either/or choice among alternatives. It is only after 9 months of age that young toddlers make either/or choices among alternatives.

Evidence for this interpretation comes from studies in which infants and toddlers have a prepotent tendency to go for a "wrong" option. The point is that if they succeed in overcoming this prepotent tendency, it suggests that they have attended to both alternatives and made an either/or decision. A good example is action-based object permanence tasks. If a desired object is hidden under a single cloth, 8-month-old infants quickly remove the cloth and retrieve the object. But at this same age they often make the famous A-not-B error. This error occurs in a version of the task in which the infant is confronted with an object hidden under one of two cloths. After she finds it under cloth A, it is placed in plain sight under cloth B. In this two-cloth situation, infants often search

for the hidden object under the cloth where they last found it (A), rather than where they last saw it disappear (B). They make this error through the end of early infancy, first searching reliably for the object in its new location (inhibiting any prepotent attraction to the first location) only as toddlers at around 11 months of age (Diamond, 1985; Marcovitch and Zelazo, 2006). The important point is that the single-cloth task only requires the infant to make a go/no-go decision (to remove the cloth or not), whereas in the A-not-B task she is seemingly confronted with an either/or decision between the two cloths, each of which is a salient alternative for good reason. Young infants' behavior in detour tasks is similar. If a desired object is placed behind a transparent glass barrier, infants up to 11 months of age tend to just reach directly for the toy and bang into the glass (Diamond and Gilbert, 1989; Diamond, 1990). They cannot overcome this prepotent tendency and so choose the reach-around alternative, even after seeing this prepotent tendency fail several times, which implies, again, that they are not choosing between the two alternatives but simply seeing an opportunity to grasp an object and going for it. And again toddlers after 11 months of age succeed in choosing the less salient alternative action in this task.

The hypothesis is thus that young infants' actions are generated by a process of decision making that simply determines whether to perform a particular action in the situation at hand: is this an opportunity for a particular goal-directed action? One might propose that the issue for infants is not decision making but inhibitory control, and this would not be totally incorrect. But either/or decision making and inhibitory control go hand-in-hand in the sense that choosing among options means inhibiting the unchosen option before acting. I would thus characterize the issue more broadly. The issue, in the current hypothesis, is that infants before 9 months of age do not have an executive tier of functioning that can simulate alternative action possibilities and their likely outcomes before acting, and so they do not yet have the possibility of either/or decision making with proactive inhibition of unchosen behavioral alternatives. It is interesting that attempts to measure individual differences in inhibition in infants before 9 months of age mostly involve so-called delayed response tasks (e.g., Diamond, 1990), which only measure something like global inhibition of a single action and not selective (proactive) inhibitory control of one alternative in comparison to another before acting.

2.2 Toddlers as intentional and joint agents

In contrast to young infants (before 9 months), toddlers make either/or behavioral decisions in which they imagine behavioral options with their likely outcomes and then choose one before acting. This is what Berkman et al. (2017) call "value-based choice," in which the preferred option is increased in value, and/or the less preferred option is decreased in value, relative to the other(s). Value-based choices require imaginative representations, that is, representations of actions and states of affairs that are not currently the case but could become actually the case.

One can see the origins of 9-month-old toddlers' either/or decision making already in their behavior in the two-cloth object permanence task. Soon after 9 months of age toddlers stop making the A-not-B error: they choose which of the two cloths is likely concealing the desired object and choose that one. This value-based choice involves a more flexible form of inhibitory control than the simple global inhibition characteristic of infants. As they are comparing behavioral options, choosing one involves suppressing the other, often prepotent, tendency such as removing the A cloth where the toy was previously found. In support of this interpretation, much research shows that toddlers' ability to make choices in this manner correlates strongly with other tasks measuring inhibitory control (Marcovitch and Zelazo, 2006). Moreover, either/or comparisons of this kind should take time to execute, and Kim et al. (2020) found that when 12- and 24-month-old toddlers are faced with more uncertainty in their potential choices, they take more time to decide. In general, toddlers seem to be making either/or decisions involving processes of proactive inhibitory control before acting.

Perhaps even clearer evidence for this kind of decision making comes during this same age range as toddlers make decisions in so-called opt-out tasks requiring them to compare options before choosing. A number of mammalian species—including dolphins, rats, and many non-human primates—have been confronted with a choice between an easy-to-obtain low reward and a more difficult to obtain high reward. When chances of obtaining the high reward are high, individuals will go for that; but when chances of obtaining the high reward are low, individuals often opt out and go for the easy-to-obtain low reward. Goupil et al. (2016) tested 20-month-olds in a situation with this logic (the opt-out response in this case was to request adult help) and found that toddlers made efficient choices. Further, Call and Carpenter (2001) found that when 30-month-olds felt uncertain about a decision, they actively sought more information to try to make a better decision, again showing the ability to comparatively evaluate alternative possible actions. The toddlers are monitoring their confidence or uncertainty in a value-based choice, and then responding appropriately.

But perhaps the strongest evidence comes from another experimental paradigm aimed at children's decision-making. The situation is slightly different from uncertainty monitoring in that the costs and risks of both possible choices are clear at the outset (often with one having a kind of prepotent attraction). Thus, Herrmann et al. (2015) confronted 36-month-olds with a spatial discounting task in which the child first spied a nearby small reward and then a farther-off large reward, and they were shown that going for one meant forsaking the other. They had to compare the two situations and make their choice before acting, which prevented a sequential guessing strategy involving only a sequence of go/no-go decisions. In a similar task toddlers had to choose one of two behavioral strategies given that the situation had noticeably changed, which meant inhibiting a previously successful action in favor of a new one demanded by a changed situation (again they had to choose before acting so that a sequential guessing strategy was not possible). In both of these tasks, toddlers were generally successful, equally as good as chimpanzees (but not as good as 6-year-olds).

Toddlers' behavior in all these tasks thus suggests either/or, value-based choices between two simultaneously available courses of action as they imagine them (in imaginative representations). Such value-based decision making among simultaneously available options cannot take place in creatures who operate as a simple

goal-directed control system comprising only goals, actions, and attention. Rather, it requires control systems organization with an additional executive tier of monitoring and control to regulate the process of behavioral decision making.

In addition, from around their first birthdays, toddlers are able to form joint agencies with adults to do such things as build a block tower together, get the child dressed together, or walk the dog together. To create such joint agencies the two parties need to coordinate their actions and attention. One- and two-year-old toddlers are notoriously poor at coordinating with same-age peers (Brownell and Carriger, 1990), and they do not seem to participate in joint attention with same-age peers in anything like the way they do with adults either (see Tomasello, 2020a; for a review). The implication is that toddlers cannot really make joint decisions with others, but they can participate in joint agencies when an adult scaffolds the decision-making process. They coordinate actions and attention (but not decisions) with an adult (and not a peer) partner.

Modern conceptions of executive function view it as individual self-regulation, but joint agencies need to be self-regulated as well and this is a social process. In the beginning, toddlers do not participate much if at all in the coordination and self-regulation of the joint agency, as the adult scaffolds the process. But over time they come to coordinate their actions and attention with the adult more actively, sometimes by communicative acts aimed at the partner's actions and attention. My proposal is that it is these attempts at social and mental coordination with adults in joint agencies that create the uniquely human kinds of perspectival flexibility that are measured by the most basic tasks of attentional flexibility such as attention shifting, set shifting, and task switching (i.e., other species show these abilities, but not as flexibly humans). Of special importance are toddlers' newly emerging abilities of joint attention and cooperative communication that help them to establish and maintain joint agencies with others.

The process of establishing joint attention with a partner on some referential situation is not a one-shot, ballistically produced intentional action, but rather a process of cooperative coordination. Thus, indicating and identifying the referent of a pointing gesture (as done already by 12-month-olds) involves the coordination of attentional perspectives. In the prototypical case, one partner initiates things by pointing for the other to a referent that she (the communicator) is already attending to; her referential intention is the aligning of their attention in joint attention. The recipient, if he is being cooperative, goes from his own individual attention elsewhere to jointly attending with his partner. The interpersonal coordination thus involves each partner's sequential shifting from individual to joint attention, as either communicator or recipient, with adjustments as needed (Liszkowski et al., 2007). Unlike simply imagining what another person sees or knows, as occurs in many studies of infant social cognition, negotiating joint attention brings into focus the *relation* between self and other perspectives: to know that perspectives are or are not aligned there must be some imagining of the content of those perspectives and their relationship. Such negotiations require both imaginative representations and an executive workspace in which the two attentional perspectives may be imaginatively compared and coordinated.

From 9 months of age, then, toddlers are operating in a very different way from young infants. Young infants are perceiving and representing the actual world (even if it is behind an occluder at the moment). In contrast, toddlers are imagining possible courses of action and outcomes in the environment and basing their decisions on these imagined possibilities, a process which requires them to employ a kind of proactive inhibitory control in suppressing the imagined alternatives that they do not in the end choose. In addition, toddlers must coordinate attentional perspectives with adults in joint agencies, which requires them to employ a kind of attentional flexibility that is not needed by young infants (and non-human animals) who do not engage in joint agencies. Toddlers are able to do all this, in the current hypothesis, because of the maturation of a new cognitive architecture involving a single tier of executive monitoring and control, operating within a new executive workspace (executive working memory).

2.3 Preschool youngsters as metacognitive and normative agents

How animals and children use metacognition to make decisions is often studied using tasks of uncertainty monitoring. For example, when presented with a difficult discrimination or memory problem, many animal species and preschool children opt out and go for a safer alternative: in one interpretation, they know that they do not know. But there is controversy over whether opting out in such cases actually requires metacognition in the strict sense of the term (e.g., see papers in Beran et al., 2012). The key issue in the current context is whether children younger than 3 years of age are able to metacognitively reflect on the decision making process.

In a few studies researchers have claimed metacognitive decision making in 2-year-old toddlers. Specifically, in two studies already described above, when 2-year-olds were uncertain about their ability to solve a behavioral problem, they recruited a parent for help (Goupil et al., 2016), and when 2-year-olds did not see where an adult hid a toy—so they were uncertain where it was—they actively looked behind a barrier to gain needed information (Call and Carpenter, 2001). These two studies are sometimes characterized as involving metacognition under the interpretation that the toddlers "know that they do not know." However, a different interpretation is that the toddlers in these studies are not metacognitively monitoring what they do and do not know, but rather they are executively monitoring what they can and cannot do: whether proceeding with a planned action is or is not likely to be successful in reaching the goal. In the view of Goupil and Proust (2023), monitoring behavioral uncertainty in this manner is not monitoring a thought but rather monitoring a *feeling*. That is, the toddlers are executively monitoring a feeling of uncertainty as they go about choosing an action on the behavioral tier of operation, not metacognitively monitoring the executive-tier cognitive processes they are using to make that decision. Goupil and Proust (2023) actually refer to this type of uncertainty monitoring as a procedural form of metacognition, that is to say, a form that focuses not on cognition proper but on ground-level processes of action and attention. I would thus characterize these two studies as concerned with the executive supervision and control of action and attention.

Then, beginning sometime after 3 years of age, with the development of the metacognitive tier of agentive architecture, young children become able to metacognitively monitor and control not just the feeling of behavioral uncertainty but the cognitive processes involved in executive decision making itself. That is, they become able to metacognitively monitor their executive-tier processes of thinking, planning, and decision making to decide among different possible either/or decisions, including revising already made decisions and beliefs in the light of new evidence or reasons. This takes place in two different forms. One takes place within the agent's mind, as it were, as young children plan and evaluate their own executive-tier decisions before making a final decision, or perhaps reassess things after a decision has been made if new information becomes available. The other takes place between agents' minds, as it were, as young children coordinate decisions with others in joint or collective agencies, jointly attending to the beliefs and reasons involved.

First, within minds, O'Madagain et al. (2022) gave both great apes and human children (3 and 5 years of age) the opportunity to visually locate the best food at location X. The subjects did this, indicating their belief/decision by choosing that location (though not receiving the food as a result). Then, they were exposed to new information that called their initial belief into question, information suggesting that the best food might be in location Y. Subjects then had the possibility to seek further information (or not) that could either confirm or disconfirm their initial belief. Many apes then actively sought more information to resolve the discrepancy between their original belief and the new information, by looking again into location X (and perhaps Y) to check their initial judgment so as to make the best decision. The apes were in this case metacognitively assessing their executive decision *after they had already made it* (which distinguishes the demands of this task from those of the two toddler studies described above); they were reflecting on the belief guiding their decision in the light of newly obtained information and discerning the need to possibly revise that belief and so decision. If this is indeed what they were doing, it is important because attempting to causally diagnose problematic decisions before they are behaviorally executed fulfills a standard criterion for reflective agency, and it clearly is metacognitive.

Like the apes, the human children in this task questioned their own belief and actively attempted to double-check it—but only at 5 years of age. The children at 3 years of age just went with one or the other choice without double-checking. However, in a second study, O'Madagain et al. (2022) provided apes and children with discrepant information in a different manner: the subject made an initial choice, again without receiving anything as a result, and then a conspecific entered and indicated a different choice. In this case, the apes did not double-check their initial choice, presumably because they did not compare the perspectives of themselves and the peer. In contrast, the human children actively double-checked their initial choice, and they did so even at 3 years of age! This suggests that, in contrast with apes, young children find different perspectives emanating from social partners to be more salient indicators of the need for belief revision than new information emanating from the physical world. In their individual decision making, young children are especially attuned to discrepant social perspectives, which prompt them (i.e., more strongly than physical evidence) to metacognitively reflect on and revise their beliefs and so decisions.

Second, between minds, in shared agencies preschool children for the first time begin to mentally coordinate with peers to make truly joint decisions in joint agencies. Whereas 2-year-old toddlers can to some degree coordinate their ongoing actions and attention with adults, preschool children can plan and coordinate their actual *decisions* with others, including peers. The process of coordinating not just actions but decisions is studied formally in game theory in what are called coordination games. A well-known coordination game is the stag hunt. In the classic parable, I am hunting alone for hares when I spy a stag, which is more and better food but which I cannot capture alone. You are in the same situation, and so it is in both our interests to drop our pursuit of hares and collaborate to capture the stag. The problem is that neither of us can be certain that the other will choose to go for the stag (maybe our partner did not see or hear the stag). Chimpanzees do not perceive the stag hunt as a dilemma: they just go for the stag and hope the other will follow. But 4-year-old children perceive the dilemma and so before leaving the hare they communicate to make a joint decision (Duguid et al., 2014). They are monitoring their partner and the possibilities for fruitful collaboration and making their behavioral decisions accordingly. Four- and 5-year-old preschoolers can even coordinate their decisions in situations in which the possibility of communication is eliminated, that is, in games of so-called "pure coordination" (which great apes cannot do; Duguid et al., 2020). That is, they are able to coordinate their decisions if there is some salient feature of one of the choices—e.g., one is red while all the others are white—which they can metacognitively predict will be a salient decision for their partner, whom they know is attempting to metacognitively predict their decision as well (Grüneisen et al., 2015). Moreover, children in this same age range are even able to plan a coordinated decision in a joint problem-solving situation by each partner determining which tool each of them must choose in her role and then coordinating their respective choices accordingly (Warneken et al., 2014).

Once a joint agency with a peer is formed, preschool youngsters attempt to self-regulate it through various forms of action and communication. For example, if the peer does not play her role adequately in their collaboration, the child protests normatively using words such as *should* or *must* or *ought*—to bring the wayward partner back into line. Often preschool peers initiate a collaborative activity with a joint commitment ("Let's do X," agreed to with "OK"), and so the normative protest is then referring the partner back to "our" agreement to collaborate. That is to say, the child is self-regulating the collaborative activity, in an important sense collaboratively, by referencing the original formation of the shared agency and their individual responsibilities in it. This kind of normative self-regulation can be characterized as we > me normative self-regulation (Tomasello, 2020b).

In more discourse-based studies of decision making with peers, pairs of 3- and 5-year-olds are able to coordinate a joint decision by metacognitively comparing their different beliefs and even reasons for their beliefs—through perspective-taking discourse and joint reasoning. For example, in one study peer partners had different information from different sources about what some novel

creatures typically eat. To resolve the issue, they metacognitively discussed the validity of the evidential sources from which they each had obtained their information (hearsay vs. direct observation) and came to a reasoned joint decision as a result (Köymen and Tomasello, 2018). The point is that in these joint problem-solving situations peers coordinate not just their actions but their decisions, which requires each of them to metacognitively monitor both their own and the partner's beliefs, as well as their respective reasons for their beliefs (see Köymen and Tomasello, 2020, for a review of these and similar studies).

Preschool youngsters are able to coordinate and regulate their decisions with peers because they are now operating with a new metacognitive tier of functioning that enables them to conceptualize and socially coordinate executive-tier cognitive processes such as beliefs and reasons, with which they, from 3 to 4 years of age, are operating. The Vygotskian hypothesis is that it is precisely this kind of social coordination of beliefs, reasons, and decisions with others that is the original source of preschool children's individual cognitive flexibility and conceptual perspective taking, as they internalize the social process into an internal dialogue which they use to deliberate on their own. The O'Madagain et al. (2022) study described above (in which children metacognitively examined their own beliefs more readily in the face of a discrepant social perspective than discrepant physical information) is generally consistent with this view. Also supportive is the study of Köymen et al. (2020) in which adults trained 3-year-olds in a kind of "meta-talk" about reasons, evidence, and their validity, and this led the children later to engage in more skillful joint decision making with peers.

Relatedly, there are also significant developments in individual cognitive flexibility at around 3 to 4 years of age as well. In preschoolers, cognitive flexibility is classically measured by tasks such as the Dimensional Change Card Sort task (DCCS; Zelazo, 2006). In the DCCS task children are required first to sort cards on one dimension (e.g., color) and then immediately sort them by another (e.g., shape). Early research tended to show that 3-year-old children had trouble classifying objects in a second way (see Doebel and Zelazo, 2015; for a review). But subsequent research employing more child friendly versions of the task has found that performance is quite good at 3 to 3.5 years of age whereas it is very poor at 2.5 years of age (e.g., Blakey et al., 2016). So age 3 would seem to be the key age of transition for successive multiple classification. Simultaneous multiple classification is most often assessed using a matrix completion task. In this task, children must find the missing object in a matrix created by crossing two dimensions, for example, placing a red triangle in the missing space defined by the convergence of a red vertical dimension and a triangle horizontal dimension. Again, early studies showed that 3- and 4-year-old children struggle with this task, but Podjarny et al. (2017) designed a more child friendly version and found that both 3- and 4-year-olds were quite competent. Interestingly and importantly, Podjarny et al. (2022) administered child friendly versions of both a successive and simultaneous task of multiple classification and found that young children were consistently better at the successive version.

What explains this relatively sudden competence at 3 to 4 years? Based on a series of nine studies using the DCCS (as well as a review of relevant literature), Zelazo et al. (2003) concluded that children's performance was not best explained by developments either in memory or in inhibitory control. The best explanation was what they called a "redescription account" (championed most prominently by Perner and Lang, 2002), which attributes growing success to young children's developing ability to appreciate multiple conceptual perspectives on the same object(s) at the same time. But why does this new ability emerge only at around 3 or 4 years of age? In the current account, the obvious reason is that 3 years is the age at which the new metacognitive tier of regulation emerges, and this enables children to re-represent all of the simple categorization activities in which they have been participating for several years already. So perhaps on one occasion the child labeled an object a "bird" and then on another occasion noted that it was a "cardinal," or on one occasion she singled out the ovals from a group of blocks and on another occasion singled out the blue ones. These acts create discrepancies in that the same object is conceptualized as different things on different occasions. Reflective thinking and re-representation on the metacognitive tier use these kinds of discrepant experiences as the raw material to coordinate and perhaps synthesize different conceptual perspectives on the same entities to enable multiple classification of the same object in different ways for all kinds of creative purposes, first successively and then, in certain contexts, simultaneously. This happens most frequently and most saliently in collaborative social interactions with others, including both adults and peers. Thus, if a child came to maturity on a desert island with no social interaction, she would not learn to take different perspectives on things and integrate them.

Finally, a more explicitly social kind of cognitive flexibility comes out in a variety of tasks that Perner et al. (2003) call "perspective problems," that is, problems that bring different conceptual perspectives into conflict (though this is often only apparent and can be resolved), requiring the child to do some kind of coordination of perspectives (perhaps especially with peers) to make sense of things. For example, from her viewing angle a child may see a drawing of a horse as right side up, but a partner on the other side of the table claims that it is upside down. How to resolve the situation? Further, the child may initially believe that something is a rock, but another person uses it as a sponge. How can something appear to be one thing but be used as another? Or the child may know that an object is a tree but hear someone else call it a "bush," or know that an object is a dog and hear someone else call it an "animal." How can an object be two things at once? Or, most famously, the child may know that an object has been hidden in one place but an agent who did not witness the hiding process believes it is in a different place. How to coordinate the child's own perspective, the agent's perspective, and alight on the objective perspective of where the object really is? To construct the necessary concepts to resolve these conflicts, the child needs to flexibly coordinate conceptual perspectives on the world (Tomasello, 2018). Children are typically not successful in any of these tasks (visual perspective taking, appearance reality, dual naming, or false belief) until 3 or 4 years of age. In the current hypothesis that is because they are not able to metacognitive only reflect on their own and others conceptual perspectives from a metacognitive tier of operation and

	Toddlerhood EXECUTIVE/JOINT [Executive Workspace]		Early Childhood METACOGNITIVE/COLLECTIVE [Metacognitive Workspace]	
	Reactive	**Proactive**	**Reactive**	**Proactive**
Monitor *Individual* Agency	Ongoing own action & attention	Anticipated own action & attention	Ongoing own thinking & D-M	Anticipated own thinking & D-M
Control *Individual* Agency	Bolster/inhibit own action & attention	Plan/coordinate own action & attention	Bolster/inhibit own thinking & D-M	Plan/coordinate own thinking & D-M
Monitor *Shared* Agency	Ongoing partner action & attention	Anticipated partner action & attention	Ongoing partner thinking & D-M	Anticipated partner thinking & D-M
Control *Shared* Agency	Praise/protest partner actions & attention	Direct partner action & attention	Praise/protest group thinking & D-M	Direct group thinking & D-M

FIGURE 2
Summary of what is regulated, how it is regulated, and where (in which workspace) it is regulated—for both individual and shared agencies in toddlerhood and early childhood ("D-M" refers to decision making).

coordinate them effectively which, again, occurs most readily and most saliently in their social interactions with others, especially peers, which could in principle be empirically evaluated in some kind of training study.

3 The regulation of agency

In order to bring all of the different aspects of these various self-regulatory process together, I propose focusing on three key components of agentive self-regulation: (i) what is regulated, (ii) how, via what processes, it is regulated, and (iii) where, in what cognitive workspace, it is regulated. First, the proposal is that in individual agencies during toddlerhood what is regulated is basic-level things like action and attention, whereas during early childhood it is also more cognitive things like thinking and decision making. Second, these are all regulated by processes of monitoring (a higher tier attends to one below it) and control in terms of (a) reactive processes (like reactive inhibition), and (b) proactive processes (like anticipatory coordination). Third, this is all done in either an executive workspace on an executive tier during toddlerhood or a metacognitive workspace on a metacognitive tier during early childhood—and either in individual or joint agencies. Figure 2 thus provides a typology of agentive self-regulation in terms of four main dichotomies:

- executive vs. metacognitive workspace
- monitoring vs. controlling as distinct phases of self-regulation
- reactive vs. proactive regulatory processes
- self-regulation in individual vs. shared agencies

Then, in addition, the target of regulation—what is regulated—is shown in the cells of Figure 2 in terms of what behavioral and/or cognitive processes are being regulated (and, in the case of control, a bit about how they are controlled).

The current model thus has three distinctive features relative to other treatments of executive function and metacognition in the literature. First, the model is articulated within the context of an overall theory of human agency and decision making, which provides coherence and functional continuity. Second, the model is hierarchically structured such that executive and metacognitive processes are two analogous control systems operating on different material from different tiers (workspaces) of agentive architecture—emerging at different ages. And third, the account of shared agency provides a principled account of uniquely human processes in the coordination of perspectives—both attentional and conceptual—that integrates what has traditionally been called cognitive flexibility with other processes of agentive self-regulation, as well as specifying unique processes of collaborative or normative self-regulation.

The specific mechanisms of executive and metacognitive function currently posited in the literature (often defined by cognitive tasks) simply reflect a focus on one or another sub-process in this overall regulatory architecture, or else a specific application of these. Particular tasks measure one or more of these processes made more specific in the context of that task. For example, various go/no-go tasks (e.g., delayed response) would be inhibition of action (either reactive or proactive); effortful control and emotion regulation would mostly be inhibition of emotional expression (either reactive or proactive); attention shifting and task switching would be the coordination of attention or action depending on the task; the DCCS would be coordinating

conceptual perspectives successively; matrix completion would be coordinating conceptual perspectives simultaneously; and so forth. The model thus provides a theoretical vocabulary for relating specific processes to one another. It is possible that it could be extended to older children to account for some of the phenomena of self-directed cognitive control studied by Frick and Chevalier (2023).

The current proposal is not intended to replace any of the important work that has been done in the study of either executive function or metacognition. Studies of inhibitory control, effortful control, continuous monitoring, working memory, emotion regulation, attention shifting, set shifting, task switching, etc., need to be described at a more detailed level—in terms of the specific task context and demands—than the very coarsely cut categories in the current model in Figures 1, 2. The current model is simply an attempt to provide a larger psychological framework within which current research may be categorized and interrelated. The hope is that keeping the various phenomena in their appropriate theoretical places may provide a unifying framework within which the menagerie of theoretical constructs in the field may be meaningfully interrelated and so spur further research progress.

4 Conclusion

In closing, what I am offering here is a way of unifying executive and metacognitive processes within an overall psychological architecture of agentive decision making and its self-regulation, one that unfolds in a distinctive, two-step developmental pathway. I also believe that integrating social agencies into this account provides additional dimensions of the process of agentive self-regulation especially the proactive coordination of perspectives and normative self-regulation that can broaden the scope of research into executive and metacognitive processes as they emerge and shape young children's cognitive and social development.

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