ABSTRACT

Title of Thesis:	DERIVATION OF GAIN IN A HIERARCHICAL MULTIPLE-GOAL PURSUIT MODEL
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The motivational sciences in organizational psychology have recently focused on goal pursuit as a dynamic process, using computational modeling as a methodological tool. This has resulted in a detailed specification of certain components of the goal-pursuit process, leaving others vague. The current research sheds light on one of these underspecified pieces, *gain*, through the development of the hierarchical multiple-goal pursuit model (HMGPM). The HMGPM proposes that gain, or a goal's subjectively evaluated importance, is a function of the importance of higher-order goals to which it is connected in an individual's goal network, and the strength of those connections. Through computational modeling and simulation, the HMGPM is shown to produce theoretically-plausible patterns of goal choice, replicate previous empirical findings, and advance new topics of future research. The usefulness of the HMGPM as a theory-building tool that integrates organizational and social psychological perspectives of motivation is discussed.

DERIVATION OF GAIN IN A HIERARCHICAL MULTIPLE-GOAL PURSUIT MODEL

by

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Derivation of Gain in a Hierarchical Multiple-Goal Pursuit Model

Motivation has proven to be a complex topic of study. It is not a directly observable process and involves a multitude of potential parameters, both within and external to the individual. Motivational psychologists have recognized this complexity and have typically attempted to conquer it by isolating a single piece of the problem. For some, the focus was on antecedents of behavior (e.g., Maslow, 1943; Deci, 1975), others focused on the choices involved in goal pursuit (e.g., Vroom, 1964), and still others, the feedback loops that control engagement in goal pursuit (e.g., Carver & Scheier, 1982). These approaches have traditionally viewed motivation as static. Even those focused on engagement in goal pursuit, a concept with an inseparable temporal component, provided little specification as to how relevant parameters change over time. The field's current mission takes a more holistic approach, integrating these three previously separate perspectives and treating motivation as a dynamic process.

While motivational researchers, especially in the field of organizational psychology, have made great strides in addressing the shortcomings of traditional theories, parameters remain underspecified despite being consistently theorized in the literature. The current project intends to shed light on one of these parameters, namely *value*. Motivational theories have carved out a place for value since Maslow's (1943) hierarchy of needs, though it has undergone a number of transformations. The contemporary conceptualization of value is most generally the importance an individual places on the attainment of a particular goal. It has been relatively well established that one key player in determining value is the distance one perceives themselves to be away from goal-attainment. The second component of value, *gain* (Vancouver, 2008;

Vancouver, Weinhardt, & Schmidt, 2010; Ballard, Yeo, Loft, Vancouver, & Neal, 2016), speaks more directly to the subjective evaluation of goal importance, but has hardly been detailed.

Consequently, the primary goal of the present research is to improve the specification of gain derivation in contemporary theories of motivation. More specifically, a computational model and theory will be developed that integrates nested goal hierarchies (Powers, 1973) with dynamic models of motivation to explore goal pursuit in multiple-goal environments. In addition to advancing current motivational theories, the model will be used to critically examine findings and conclusions based on existing research; pose new research questions and hypotheses for future empirical study; and explore potential implications and applications for influencing motivation in the context of multiple-goal hierarchies.

The following sections provide an overview of traditional motivational theories that inform the current project and situate the model among the most recent conceptualizations of the goal-pursuit process.

Traditional Theories of Goal Pursuit

Theories of motivation can be categorized into three types: need-motive-value theories, cognitive choice theories, and self-regulation theories (Kanfer, 1990). All three will be addressed below, but the latter two laid the groundwork for motivation to be viewed as a dynamic process and are thus especially important to the current state of the field and the development of the proposed model.

Need-Motive-Value Theories

Need-motive-value theories suggest that behavior is driven by tensions that arise within an individual when a specific need is unmet. These needs, ranging from the physiological (like hunger) to those related to self-fulfillment, are assumed to be innate and dispositional. Some theories even characterize needs as universal, such that every individual has the same set of basic needs (e.g., Maslow's, 1943, need hierarchy theory).

Two of the most well-known theories in this category are Maslow's need hierarchy theory (1943) and Alderfer's existence-relatedness-growth theory (1969). In Maslow's (1943) theory, needs are arrayed into five hierarchical levels (from lowest to highest): physiological, safety, belongingness, esteem, and self-actualization. He theorized that motivation arises from the demand to fulfill specific needs at each level. Furthermore, individuals move upward through this hierarchy as goals at each level are met, such that satisfying a lower need allows the pursuit of the next highest need (i.e., the prepotency principle). Alderfer (1969) simplified the hierarchy by theorizing only three categories of needs: existence (encompassing Maslow's physiological and safety needs), relatedness (encompassing Maslow's belongingness and esteem needs), and growth (similar to Maslow's self-actualization). Though arranged hierarchically, Alderfer suggested these needs operate simultaneously, such that an individual could attempt to fulfill any need at any given time without lower-level needs having been attained. Both Alderfer (1969) and Maslow (1943) believed the highest need (growth or self-actualization, respectively) is never fully satisfied.

Intrinsic motivation, or behavior that is driven internally versus externally, is the focus of most other need-motive-value theories. Early theories of intrinsic motivation emphasized curiosity (Berlyne, 1966; Hunt, 1965), suggesting individuals have a continual need for stimulation. Others, like White (1959), suggested that individuals have an enduring need to demonstrate and exercise competence and mastery. DeCharms (1968) and Deci (1975) emphasized the need for control over one's environment. The most popular contemporary theory of intrinsic motivation is Deci and Ryan's self-determination theory (SDT; 1980, 1985, 1991). SDT proposes the intrinsic psychological needs of competence, autonomy, and relatedness. This set of needs, to some degree, encompasses those that had been previously theorized. Beyond detailing the distinction between extrinsic and intrinsic motivation, SDT also theorizes how an extrinsically motivated behavior may become intrinsically motivated as they become integrated with the self (Deci & Ryan, 1985; Deci & Ryan, 2000).

One of the most significant challenges faced by need-motive-value theories is how to best determine the universality of any particular goal or value. Researchers have not yet identified or agreed upon a single set of universal goals or needs, though there is evidence that certain concepts may be more robust. For example, the fulfillment of SDT's autonomy, competence, and relatedness, as well as the value of "safety," as in consistency or predictability, is typically salient when recalling past positive experiences (Sheldon, Elliot, Kim, & Kasser, 2001). With respect to the current model, no specific needs are identified as universal; however, it does recognize that certain intrinsic needs or values may be conceptualized at higher – and therefore potentially more universal – levels of abstraction within an individual's goal framework.

Another challenge faced by need-motive-value theories is their lack of attention to motivation as a process. They do not speak to how individuals update their beliefs regarding their level of attainment of their current goal. Further, need-motive-value theories do not include a component regarding an individual's expectations that a given goal could be attained. Rather, theories in this category assume that if a need discrepancy is perceived, an individual will automatically work to fulfill that need whether or not they believe they will be successful in doing so. Finally, beyond Maslow's (1943) prepotency principle, need-motive-value theories do not specify how an individual chooses to pursue any particular need from a set of needs. If Alderfer (1969) is correct in that needs operate simultaneously, how might an individual decide to fulfill one need over others, or alternate between two, with their limited set of resources in a given moment? The theories in the following categories along with the current model attempt to reconcile these issues.

Cognitive Choice Theories

Many theories of motivation have emphasized the importance of decision-making in the context of goal pursuit. For example, Campbell and Pritchard (1976) characterized motivation as a series of three choices: to initiate effort, to expend a certain amount of effort, and to persist in expending that effort. Similarly, Naylor, Pritchard, and Ilgen (1980) acknowledged the consideration of future consequences (e.g., success versus failure) in the initiation of and persistence in goal pursuit. In some form or another, cognitive choice theories suggest individuals evaluate two constructs in the decision making process: *expectancy*, or the likelihood of successfully carrying out a behavior, and *value*, or the consequences of carrying out the behavior. These two determinants are combined in some fashion to characterize the perceived or expected *utility* for a given behavior to help them achieve goals. Goal choice is subsequently operationalized as a comparison and selection process amongst the utilities for a given set of behaviors based on a particular rule, such as maximization. In cognitive choice theories, motivation is thus conceptualized as the integration of expectations and perceived utilities in the evaluation of alternative courses of action (Kanfer, 1990). They address processes through the point of goal selection, but do not theorize how pursuit of the selected goal is carried out.

Atkinson's (1957) theory of achievement motivation is representative of the classic approach to cognitive choice in motivation (Kanfer, 1990). Atkinson (1957) proposed that goal pursuit is determined by an individual's motive to achieve success and avoid failure, the probability of success, and the value of that success. Extensions of this theory allowed value to be assessed independently of success, implying an individual could evaluate a goal as highly desirable even if they do not expect to attain it. Vroom's valence-instrumentality-expectancy (VIE) theory (1964) is the most well-known extension of the theory of achievement motivation. VIE theory proposed that goal pursuit is determined by 1) perceived effort-performance expectancies (i.e., that the effort expended will lead to a given level of performance), 2) perceived instrumentalities (i.e., that a given level of performance will lead to a particular outcome), and 3) the evaluation of the outcome on the basis of valences (i.e., the attractiveness of the outcome). Like in most cognitive choice theories, these three determinants—valence, instrumentality, and expectancy—are combined to result in a motivational force for any particular behavior. VIE theory (1964) specifies that they are combined multiplicatively, such that no motivational force exists if one or more of the three components are lacking.

Another valuable extension of Atkinson's classic theory is Raynor's (1969) theory of future orientation effects and achievement motivation. Raynor added a temporal component by proposing that the motivation for an immediate behavior is influenced by an individual's perception of how that behavior will affect their opportunity to pursue future goals. In these "contingent-path situations", the probability of success and value of success in determining an individual's tendency to approach a particular behavior is a summation of all the combined probabilities and values of success of all goals in that path (Raynor & Entin, 1982).

Though the goal networks in cognitive choice theories are not explicitly hierarchical, both Raynor's and Vroom's conceptualizations are compatible with a hierarchical structure. Raynor (1982) implies a network of goals where the outcome (i.e., success versus failure) of one particular instance of goal pursuit serves as input to another instance of goal pursuit in a chain. The influence of future goals can be incorporated into Vroom's (1964) model by conceptualizing instrumentality as the sufficiency for a given level of effort to attain the next step in a goal chain (Kanfer, 1990).

More explicitly placing goal choice in a hierarchical framework could address one major challenge of cognitive choice theories – determining how the valence of a choice of action is derived. Monetary pay is a common operationalization of the attractiveness of an outcome (e.g., researchers attach different monetary rewards to different action outcomes to manipulate valence; Ilgen, Nebeker, & Pritchard, 1981; Kanfer, 1990). The subjective attractiveness of outcomes is a typical way of measuring valence (Ilgen et al., 1981), but *how* individuals evaluate attractiveness is not an element of cognitive choice theories. The current model proposes how the derivation of valence can be more precisely specified by considering the superordinate goals in an individual's goal hierarchy.

Another limitation of cognitive choice theories is their episodic nature. In the evaluation of alternative actions, expectancies and valences are calculated for those specific actions in a specific situation. Cognitive choice theories do not address the process by which expectancies and valences may change over the course of goal pursuit. The theories discussed next are both more explicit in their hierarchical nature and emphasize motivation as a dynamic process versus a snapshot choice.

Self-Regulation Theories

Self-regulation theories emphasize constructs that control engagement in goal pursuit, rather than specifying the goals that individuals pursue or how they choose among alternatives. They address the transformation of motivational force, the emergence of which is the focus of the theories described so far, into behavior (Kanfer, 1990). Carver and Scheier's (1982) theory of self-regulation is the most relevant to the development of this project's model. Carver (1979) initially theorized a cybernetic model of self-attention, in which an individual searches their environment or within themselves for cues that imply the need for behavior. If a cue, or behavioral standard, is salient, the individual evaluates the discrepancy between their current state and the standard, then engages in behavior intended to reduce that discrepancy. The outcomes of that attempt at discrepancy-reduction then influence the individual's evaluation of themselves.

Carver and Scheier's (1982) control theory proposes a cybernetic process similar to Carver's (1979) model of self-attention, sans the self-evaluation component. In control theory, self-regulation is conceptualized as a negative feedback loop. The loop can be boiled down to an input function, a comparator, and an output function. The input function is an individual's perception of their current state. Through the comparator, the input function is evaluated against a reference value, representing the desired end state. If this comparison results in a discrepancy, the individual engages in some behavior (the output function). This behavior is intended to impact the environment and thereby their perception, ideally reducing the discrepancy between their current and desired states (Figure 1; Carver & Scheier, 1982).

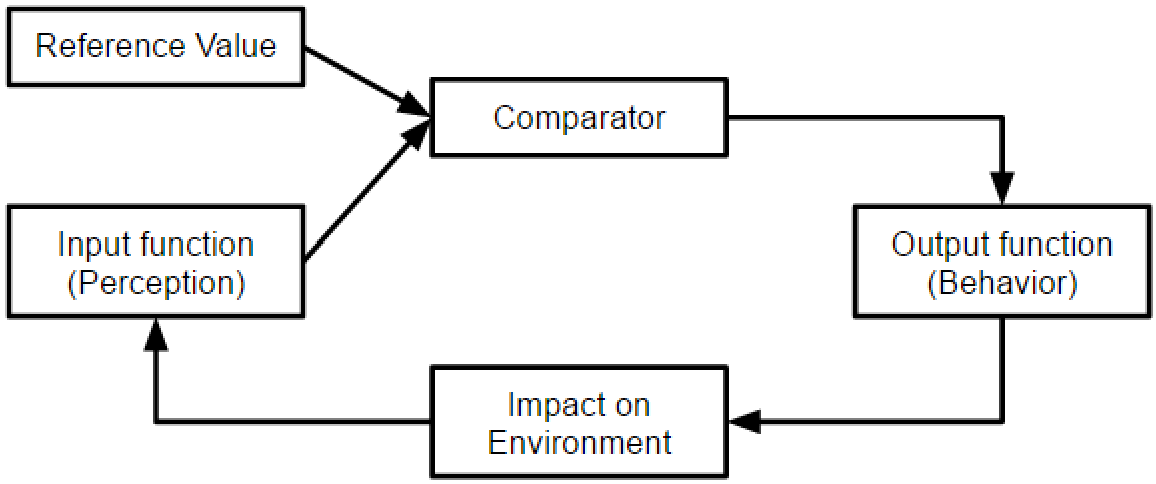

Figure 1. Carver & Scheier's (1982) control theory of motivation.

Carver and Scheier's theory relies on a hierarchical goal structure, first suggested by Powers (1973), to specify the origins of an individual's standard to which they compare their performance. In this structure, a superordinate feedback loop provides the reference value for its immediate subordinate loop. Powers (1973) proposed a specific hierarchy, where an individual's self-concept is at the most superordinate level and directs a series of subordinate feedback loops, the lowest of which being the muscle tensions required to carry out a behavior. The current model makes use of this hierarchical structure, but remains general in the labels given to each level, simply referring to them as subordinate or superordinate goals.

Contemporary Models of Goal Pursuit

While control theory lays the foundation for goal pursuit as a process, it does not speak to the initial decision to pursue a specific goal, as addressed by cognitive choice theories. Further, it has been recognized that simultaneously pursuing multiple goals is the norm over single goal pursuit (Kruglanski, Shah, Fishbach, Friedman, Chun, & Sleeth-Keppler, 2002; Vancouver, Weinhardt, & Schmidt, 2010). Although control theory describes how multiple “vertical” goals are interconnected, it does not provide an adequate description of motivation and goal pursuit when multiple “lateral” goals are present. The integration of cognitive choice theories and self-regulation theories in a dynamic, multiple-goal context has become one of the focal points in contemporary research on motivation. Because of the complexity in integrating the decision component and the regulation component of goal pursuit, as well as the emphasis on motivation as a process, many recent theories have moved beyond verbal formulations and utilize formal, computational models to explicate motivational processes. The current project follows in these footsteps.

Multiple-Goal Pursuit Model

Similar to Carver and Scheier’s (1982) control theory, Vancouver, Weinhardt, and Schmidt’s (2010) multiple-goal pursuit model (MGPM) also adopts a cybernetic approach to self-regulation (first detailed in Vancouver, 2008). Each goal exists within a negative feedback system. An input function represents an individual’s perception of their current level of performance in pursuit of the goal. This perception is compared to the desired state, and responses to any resulting discrepancy are represented by an output function. Whereas previous theories suggested the output, or behavior, was solely determined by that discrepancy, MGPM adds a weighting term, which they refer to as *gain*. Gain represents the extent to which an individual values the goal, or places importance on the goal. This addition implies that a discrepancy may not spark behavior if the goal is not valued, or that a low discrepancy may result in a disproportionate response if the goal is highly valued. This combination of discrepancy and gain results in a dynamic valence component that changes with progress toward the goal (i.e., discrepancy-reduction). The loop is closed through the effect of the behavior on the environment, which the regulator uses to update their perceptions of their current state.

In incorporating cognitive choice theories and self-regulation theories, the MGPM also adds expectancy to its self-regulatory loop. Like valence, this component is also modeled dynamically. An individual holds a belief about the rate by which their behavior can change their current state by some amount. This rate is multiplied by the amount of change still needed in order to eliminate the discrepancy between their current state and the standard. This multiplication results in a prediction about the amount of time needed to complete the task. This predicted time is compared to the actual amount of time the individual perceives to have left. Their perception regarding the amount of time they have remaining is the output from a time agent – another component not previously modeled. The time agent compares the current time

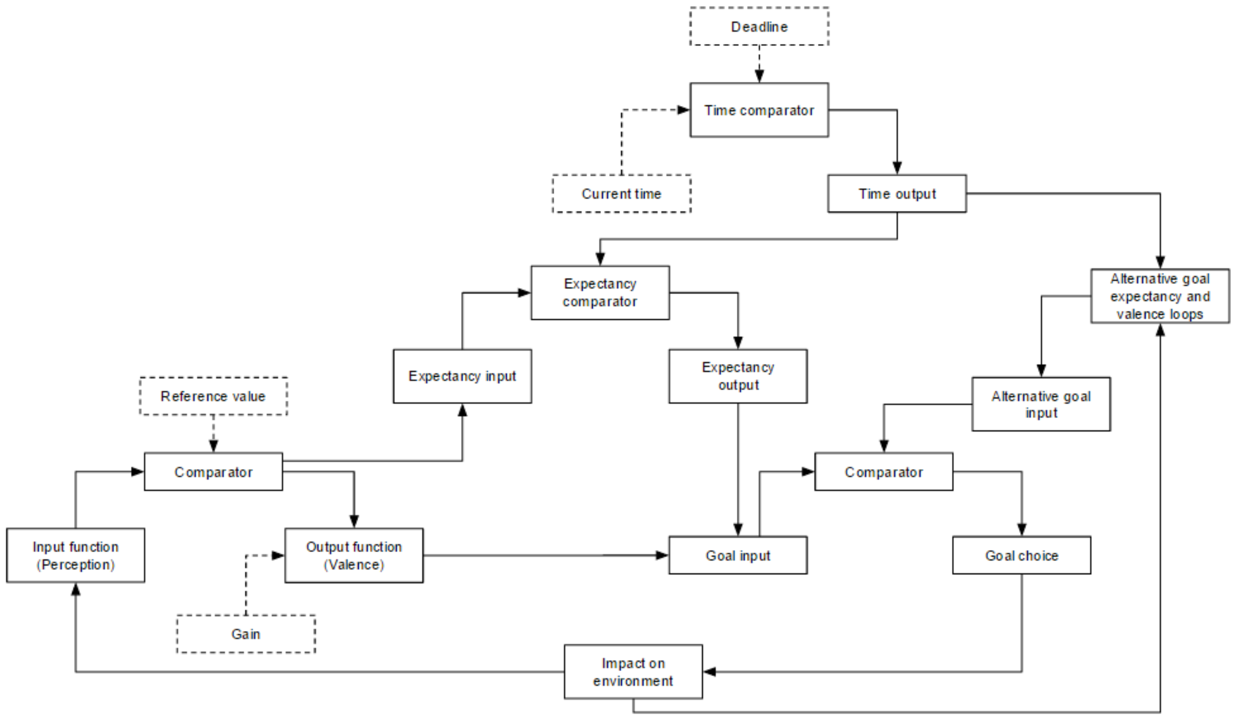

Figure 2. Vancouver, Weinhardt, & Schmidt's (2010) multiple-goal pursuit model. This is a simplified representation, detailing the loop for one of the two goals. The alternative goal loop operates identically to the loop detailed here.

with a deadline to arrive at the amount of time remaining. Importantly, because the expectancy component relies on this time component, the MGPM is only representative of self-regulatory situations with a deadline (Figure 2).

The addition of expectancy and a deadline allows self-regulation to be viewed in a multiple-goal framework (in this case, a two-goal framework). For both goals, an expected utility is calculated by multiplying the expectancy output by the task output. These two expected utilities are compared to one another, and the goal with the highest expected utility is chosen to be pursued. Given the dynamism of both components used to calculate expected utility, an individual may alternate between the two goals for every loop through the system.

Vancouver et al., (2010) were able to demonstrate that their MGPM could account for empirical findings reported by Schmidt and DeShon (2007) that originally could not

be explained by control theory. Specifically, Schmidt and DeShon (2007) observed that when
working on two scheduling tasks with one deadline, individuals initially devoted more time to the task with the highest discrepancy (i.e., with the greatest number of people waiting to be scheduled). This is consistent with Carver and Scheier's (1982) theorizing that self-regulation is driven by discrepancy. However, this behavior switched as the deadline approached. As the time remaining decreased, individuals devoted more time to the task with *less* discrepancy. Though counterintuitive to control theory, the MGPM offered a reasonable explanation. Early in the dual-scheduling task, expectancy was relatively equal across the two goals; thus expected utility and therefore task-choice was entirely driven by valence (specifically, the discrepancy component of valence). As the deadline approached, however, the expectancy of completing the task not chosen begins to sharply decrease. The large difference in expectancies between the two goals thus became a more significant driver of task choice and led to individuals prioritizing the goal they believe had a better chance of being completed before the deadline.

Multiple-Goal Pursuit Model*

Recently, an updated multiple-goal pursuit model (MGPM*; Ballard, Yeo, Loft, Vancouver, & Neal, 2016) has been introduced to allow for different types of goals to be represented in the model. Most research on goal pursuit has focused on approach goals (i.e., desirable states that individuals want to move toward), while little has been done regarding avoidance goals (undesirable states that individuals want to move away from; Elliot & Covington, 2001). This distinction in goal orientation has long been noted in the motivational literature (e.g., Higgins, 1997; Elliot & Church, 1997), but the original formulation of Vancouver et al.'s (2010) MGPM was unable to accommodate goals with different operationalizations of valence discrepancies. The differentiation between moving toward versus keeping away from a particular end state requires a more flexible conceptualization of the valence component of self-regulatory loops, which typically involve approach goals and emphasize discrepancy-reduction. Regulation of avoidance goals, on the other hand, requires behavior that increases discrepancy. Take, for example, an employee whose goal is to avoid a negative performance review versus an employee who desires a positive performance review. The actions taken by the former are intended to keep (or increase) distance from an undesirable state, while the actions taken by the latter are intended to decrease distance between their current state and a desirable state.

In order to accommodate both goal types, the MGPM* added an intercept to the calculation of valence (originally computed by multiplying discrepancy by gain) that specifies the valence of the goal when there is no discrepancy. For approach goals, the intercept is equal to 0, since the goal is desirable and equalizing one's current state and that desired state is intended. For avoidance goals, the intercept is greater than 0, meaning a current state that is equal to the undesired state will motivate behavior. In addition to this intercept, the MGPM* also specifies that the gain parameter is negative for avoidance goals, versus positive for approach goals. Thus, valence increases as discrepancy decreases for avoidance goals, motivating behavior to increase that discrepancy.

Beyond these additions that expand the ability of the model to describe both approach and avoidance goals, the MGPM* also adopted a different computational approach to the task-choice component. Rather than specifying that task choice is driven by the comparison of expected utilities, a preference accumulation model based on decision-field theory (DFT; Busemeyer & Townsend, 1993) is used. In this formulation, the value of an action is a combination of its *quality*, or the perceived impact of the consequence of the action, and the *discrepancy* between a goal and its current state. Consistent with the formulation of DFT however, a given action may have multiple consequences that facilitate different goals; furthermore, an individual is only capable of focusing on one consequence of an action at a time. Consequently, it is assumed that individuals shift their attention between potential consequences over time as they deliberate over which goal-relevant action to take (Busemeyer & Townsend, 1993). The resultant value of this computation is combined with expectancies to produce a *momentary motivational attractiveness* – the assessed utility of an action in terms of the consequence attended to. This process repeats over time and the momentary motivational values are accumulated until a threshold is reached indicating a preference for one action over the other. The addition of momentary motivational attractiveness and preference accumulation reflects a significant operational difference between the MGPM* approach to task choice and the more "holistic" comparison of expected utilities used in the original MGPM.

Limitations of Current Multiple-Goal Pursuit Models

While Vancouver and colleagues' (2010) MGPM and Ballard et al.'s (2016) MGPM* together are the most comprehensive formulation of the motivational process yet, the valence component remains underspecified. This is a critical piece worth further exploration, since it determines how goal choice and pursuit is carried out when the expectancies of multiple goals are equal. The discrepancy component, being simply the difference between an individual's current state and their desired state, is relatively clear and easily formulated mathematically. Thus, the current project will address this need for detail by focusing on the *gain* component of valence. By doing so, it will provide an explanation for tendencies in goal choice observed in the literature and reveal how these tendencies affect goal pursuit over time.

Contributions of the Hierarchical Multiple-Goal Pursuit Model

Derivation of Gain

The current model, referred to as the hierarchical multiple-goal pursuit model (HMGPM), emphasizes the associative, hierarchical structure of goal networks, in which a superordinate goal is cognitively connected to subordinate goals. The subordinate goal may be connected to any number of superordinate goals (Kruglanski et al., 2002). A subordinate goal connected to two or more superordinate goals is considered *multifinal,* whereas a subordinate goal connected to a single superordinate goal is *unifinal* (Kruglanski, Kopetz, Belanger, Chun, Orehek, & Fishbach, 2013). Though an individual's network of goals is likely expansive, only the *activated* subordinate and superordinate goals are considered in the current model.

The strength of the connection (i.e., *instrumentality*) between a subordinate goal and a superordinate goal represents the degree to which attainment of the subordinate goal translates to attainment of the superordinate goal (Zhang, Fishbach, & Kruglanski, 2007). This strength may be determined by one's belief about the relationship between the subordinate and superordinate goals, but is also influenced by the number of superordinate goals connected to a single subordinate goal. As the number of superordinate goals one subordinate goal is associated with (i.e., its multifinality) increases, the instrumentality between that subordinate goal and any single superordinate goal decreases (Kruglanski et al., 2002; Zhang et al., 2007). Beyond simply representing the association between goals, these connections act as bridges across which motivational properties of one goal transfer to a connected goal in proportion to instrumentality (Kruglanski et al., 2002). Thus, the perceived importance or value of a superordinate goal is transferred to the subordinate goal and attainment of the subordinate goal is transferred to the superordinate goal, both by a factor equivalent to the associated instrumentality.

Previously, *gain* has been described as the perceived importance of a goal without clarification of the process by which that perception is generated. The HMGPM proposes that a subordinate goal's gain is a function of its associated superordinate goals. Each superordinate goal possesses a baseline perceived level of importance to an individual, referred to as *need* in the current model. This baseline need may be conceptualized as an individual difference. For example, some individuals have a higher need for belonging, while others have a lower need, requiring fewer interpersonal relationships for satisfaction (Kelly, 2001). An individual's perceived importance of a superordinate goal may fluctuate from that baseline need, such as when ostracism leads participants to refortify their need for belonging by increasing their conformity to group norms (Williams, Cheung, & Choi, 2000). In the HMGPM, this fluctuation is captured in the degree to which a superordinate goal is more *salient* to an individual compared to other superordinate goals in a given moment. Thus, the combination of *need* and *salience* results in a superordinate goal's perceived importance. This combination is specified further below.

Associative connections play a critical role in how these two characteristics of superordinate goals influence the perceived importance of a subordinate goal. As described, the degree of transference of the perceived importance of superordinate goals to subordinate goals as well as the accomplishment of subordinate goals to the need satisfaction of superordinate goals is proportional to the connection strength, or instrumentality, between subordinate and superordinate goals. If the instrumentality between a subordinate goal and a superordinate goal is very low, the importance of the superordinate goal will do little to influence the importance of the subordinate goal. Alternatively, if the connection strength is at its maximum (i.e., there is

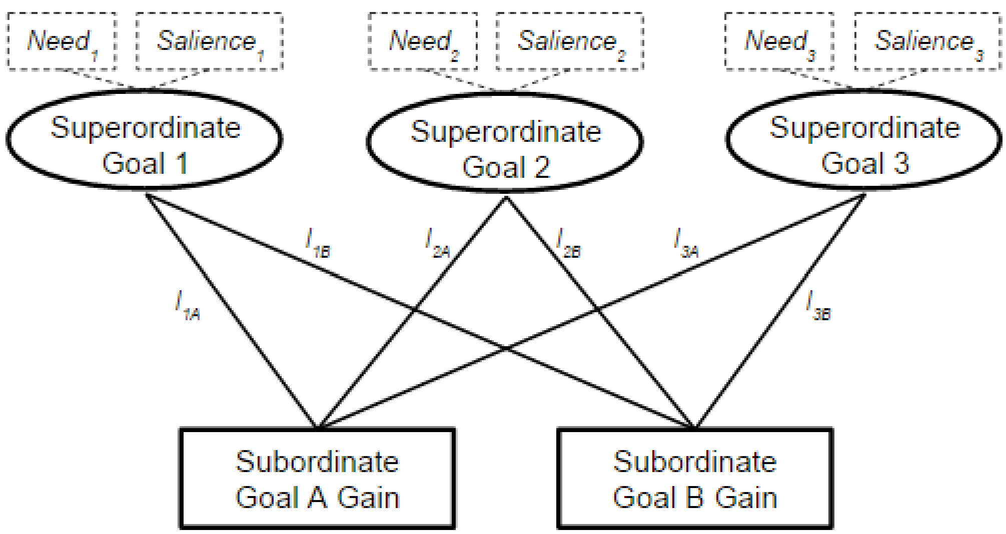

Figure 3. Associative, hierarchical goal structure. Each superordinate goal has a need and salience, and each connection between subordinate goals and superordinate goals has an instrumentality (*I*).

a one-to-one relationship between the superordinate and subordinate goals), the subordinate goal will only be as important as the superordinate goal.

Until this point, the derivation of a subordinate goal's gain has been in a single-superordinate goal context. However, a subordinate goal may be connected to any number of superordinate goals, each with its own level of need, relative salience, and associated instrumentality with the subordinate goal. The HMGPM proposes that the total gain of a subordinate goal is a combination of its associated superordinate goals' characteristics, scaled by their respective instrumentalities (see Figure 3).

Dynamic Superordinate Need

While instrumentality remains fixed in this model, the need of a superordinate goal is likely to be dynamic and change as goal pursuit is carried out. One component of goal pursuit that influences need is discrepancy, or the difference between the individual's current state and desired state at the subordinate level. Carver and Scheier (1982), based on Powers' (1973) goal hierarchy, proposed superordinate systems set reference values for their immediate subordinate

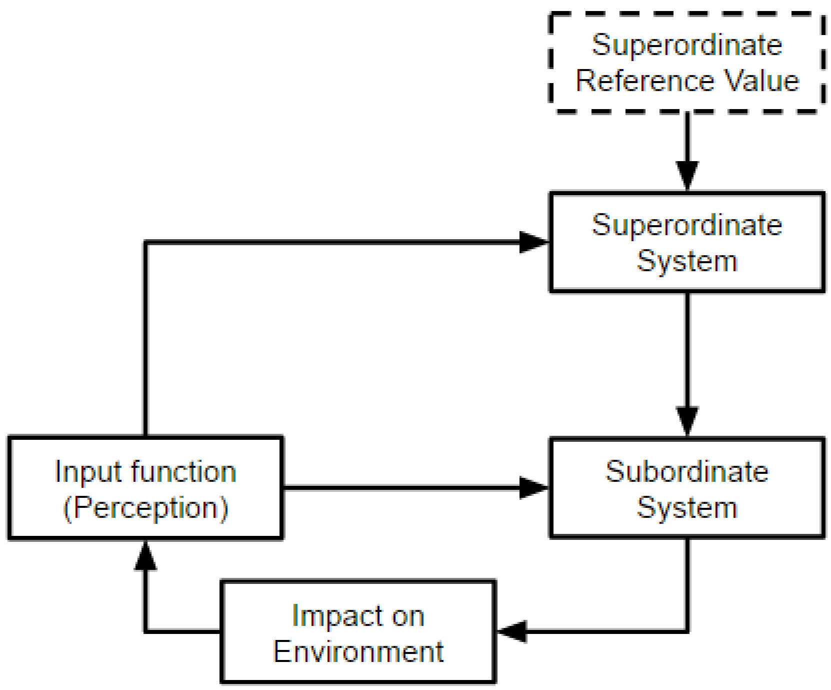

Figure 4. Example of goal hierarchy adapted from Carver & Scheier (1982).

systems. While its hierarchy is constrained to two levels, the superordinate goals in the current model have some associated reference value that signal attainment, or satisfaction of that goal. A superordinate goal's baseline need is conceptualized as the discrepancy from that goal's reference value. The effect on the environment that occurs as a result of the behavior induced by subordinate goal discrepancy serves as input for all levels of the system (Carver & Scheier, 1982; Figure 4). Thus, any progress made at the subordinate level affects the perceived state for that level and its superordinate level. Using this logic, the HMGPM proposes that discrepancy reduction at the subordinate level translates to need reduction at the superordinate level. A more detailed description of the dynamics of superordinate need is given in the following section.

Description of the HMGPM

The HMGPM builds from previous multiple-goal pursuit models. Components common with these previous models are described first, for which the formulations are as given in Ballard et al.'s (2016) MGPM*, but in a subordinate-superordinate goal context. A detailed description of the components contributed by the current model follows this summary.

MGPM* Formulation Summary

Subordinate goals serve as reference values (*g*) to which an individual's current state is compared. This comparison results in a discrepancy (*d*), which serves as input to the various components of the model. There is also assumed to be a common deadline for attainment of the subordinate goals, which serves as input to the expectancy component of the model.

Valence. Each subordinate goal *k*'s discrepancy is transformed into a valence (v), representing the utility of acting on the subordinate goal at a given time point (t). This transformation uses information about the valence when the current state is equal to the reference value (i.e., when discrepancy is zero; b) and *gain* (κ). The valence of acting on an approach goal is zero when discrepancy is zero, because the goal has been attained. The valence of acting on an avoidance goal, however, is some value greater than zero when discrepancy is zero, since the intent is to avoid the equality of one's current state and the avoidance goal. Gain also captures a critical difference between the valence of approach and avoidance goals. Detailed further in the section describing the current model's additions, gain represents the subjective importance of acting on the subordinate goal and is a weight on discrepancy. For approach goals, since valence should increase as discrepancy increases, gain is positive. For avoidance goals, the gain component negative – the need to act on an avoidance goal should increase as discrepancy decreases. Valence cannot be less than zero.

$$v_k(t) = \max[b_k + \kappa_k(t) \cdot d_k(t), 0] \quad (1)$$

Expectancy. Expectancy (e), or the probability that the subordinate goal can be attained in the time remaining, is a function of the difference between the time available (i.e., the difference between the deadline and the current time; TA) and the time required (TR). The time required is the discrepancy weighted by an individual's belief about the amount of time it takes to change their current state in relation to the subordinate goal by some amount, termed expected lag (α).

$$TR_k(t) = d_k(t) \cdot \alpha_k(t) \quad (2)$$

In the calculation of expectancy, the difference between the time available and the time required is weighted by time sensitivity (γ), which captures individual differences in and environmental influences on reactions to deadlines. A logistic function is used because expectancy is a probability and must be bound by zero and one.

$$e_k(t) = 1 / (1 + \exp[-\gamma(TA_k(t) - TR_k(t))]) \quad (3)$$

Motivational value. The initial stage of the subordinate goal choice process begins with an expected utility (u) for each subordinate goal k. Expected utility is the product of valence and expectancy. While the expected utility of an approach goal is positively related to the expectancy of reaching the goal in the time available, the expected utility for avoidance goals is positively correlated with the expectancy of *not* reaching the goal (i.e., 1 – expectancy).

$$\text{Approach: } u_k(t) = v_k(t) \cdot e_k(t) \quad (4)$$

$$\text{Avoidance: } u_k(t) = v_k(t) \cdot [1 - e_k(t)] \quad (5)$$

The pursuit of a subordinate goal has consequences. Each consequence j has a motivational value (m), representing its attractiveness. A consequence's motivational value is the sum of the products of each subordinate goal's expected utility and the quality (q), or perceived impact on discrepancy, of that consequence for each subordinate goal. For example, if a professor had the goal of publishing 10 papers and avoiding a poor teaching rating, the quality of publishing a paper would be one for the first goal (discrepancy of the publishing goal would be reduced by one) and zero for the second goal (discrepancy of the teaching goal would be unaffected by the publication of a paper).

$$m_j(t) = \Sigma[u_k(t) \cdot q_{jk}(t)] \quad (6)$$

Momentary attractiveness. The action *i* of prioritizing one subordinate goal over the other has a momentary attractiveness (A). This momentary attractiveness is a function of each associated consequence's motivational value weighted by an attention weight (w_i). The likelihood of a consequence being attended to is the probability of the consequence occurring, thus a consequence with a higher probability of occurring is more likely to be attended to. The attention allocated to a consequence of prioritizing a subordinate goal in a given time is denoted $W_{ij}(t)$, which can take on a value of one or zero, indicating attention has been allocated to the consequence or it has not. Since only a single consequence can be attended to at one time, once a consequence has been attended to, its attention $W_{ij}(t)$ becomes one and all other consequences' attentions become zero. This results in the momentary attractiveness of the action of prioritizing one subordinate goal equaling the motivational value of the consequence attended to.

$$A_i(t) = \Sigma[W_{ij}(t) \cdot m_j(t)] \tag{7}$$

Preference. An individual's preference (P) for working on a particular subordinate goal is subsequently updated by comparing the momentary attractiveness of prioritizing either subordinate goal, then summing this difference with the preference at the previous time point.

$$P(t) = P(t - 1) + [A_1(t) - A_2(t)] \tag{8}$$

The preference must reach a threshold (θ) for a particular subordinate goal to be chosen. The threshold may relate to individual differences regarding the urgency or the carefulness of the decision maker (e.g., Brown, Rae, Bushmakin, & Rubin, 2015). Environmental factors, like time pressure, may also influence the threshold (e.g., Dror, Basola, & Busemeyer., 1999). Once the preference reaches a threshold, an individual chooses to pursue the associated subordinate goal.

Model Additions

The HMGPM specifies the gain component of valence through the addition of superordinate goals' needs and saliences, and instrumentalities between subordinate goals and superordinate goals.

Gain. In the HMGPM, the gain of a subordinate goal is derived from its associated superordinate goals. Each superordinate goal h has an associated need (n) and salience (s) that combine additively to represent the superordinate goal's perceived importance relative to other superordinate goals.

As discussed above, the connection between a subordinate goal and a superordinate goal is represented in terms of instrumentality (c). Instrumentality is conceptualized as a weight and can take on any value from zero (representing the lack of a connection between a subordinate goal and a superordinate goal) and one (representing a direct connection). As specified by Kruglanski et al. (2002) and Zhang et al. (2007), as the number of superordinate goals to which a subordinate goal is connected increases, the perceived relative instrumentality of any connection between the subordinate goal and one of the superordinate goals decreases. Thus, each "true" instrumentality of a subordinate goal is scaled by its total number of connected superordinate goals (H).

The sum of a superordinate goal's need and salience is transferred to the subordinate goal weighted by the connection's instrumentality. The instrumentality-weighted sums of each connected superordinate goal's need and salience are themselves combined additively, resulting in a subordinate goal k's gain.

$$\kappa_k = \Sigma[(n_{kh}(t) + s_{kh}(t)) \cdot (c_{kh} / H_k)] \quad (9)$$

Dynamic need. Superordinate goal needs also change once a consequence has been realized. As mentioned previously, superordinate goal need can be conceptualized as discrepancy at the superordinate level. Since characteristics at both levels are transferred across the superordinate and subordinate goals' connection, any discrepancy reduction that occurs at the subordinate level is translated into discrepancy reduction at the superordinate level, weighted by instrumentality. Thus, the change in need (Δn) at the superordinate level is equivalent to the sum of each connected subordinate goal's discrepancy reductions (i.e., decreases in discrepancy since the previous time point) scaled by their respective instrumentalities.

$$\Delta n_h = \Sigma[(d_k(t-1) - d_k(t)) \cdot (c_{hk} / H_k)] \quad (10)$$

The full HMGPM is represented in Figure 5.

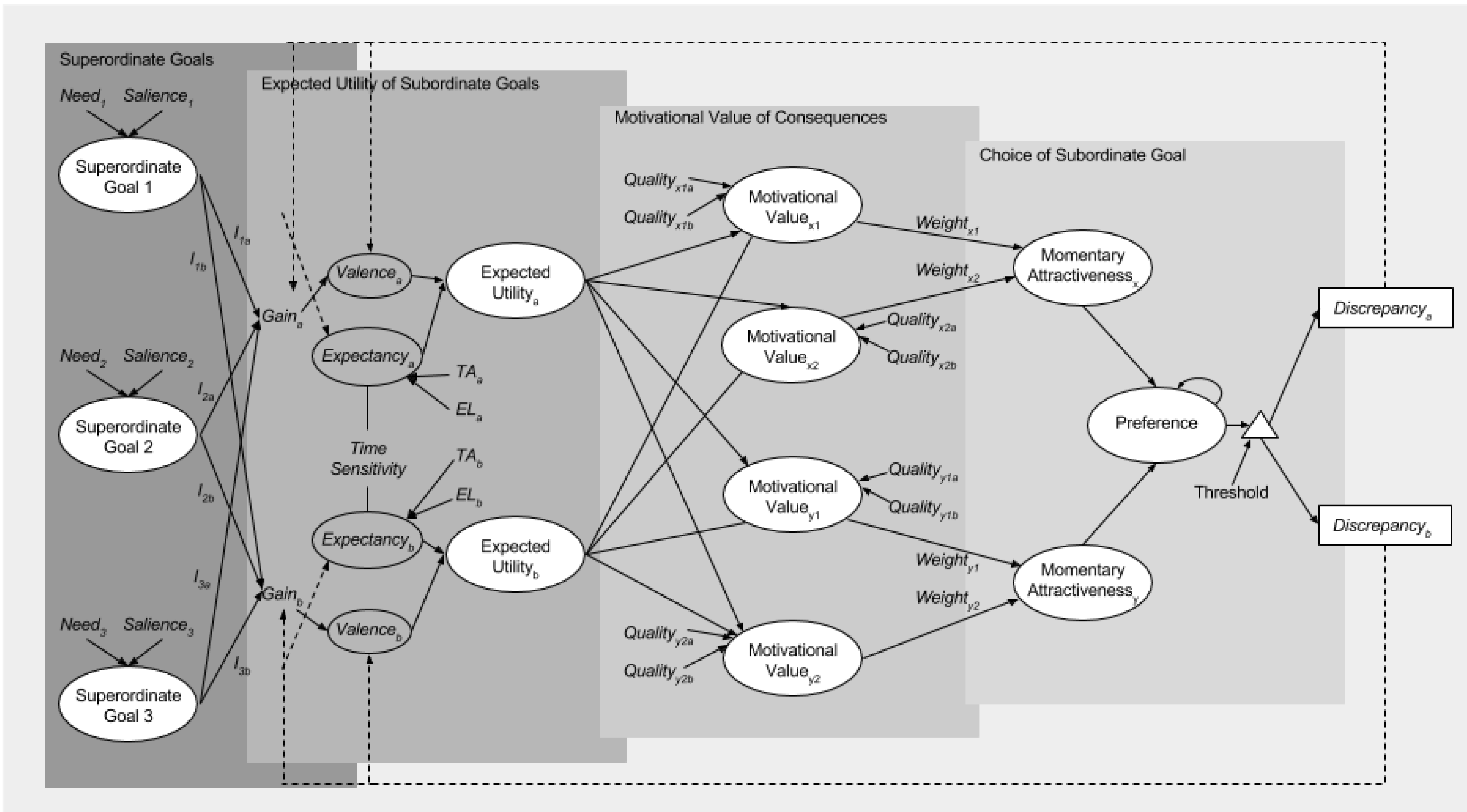

Figure 5. Hierarchical Multiple-Goal Pursuit Model. I = instrumentality; TA = time available; EL = expected lag. The influence of discrepancy on superordinate needs and saliences is depicted by connecting discrepancy to subordinate goal gain in order to simplify the figure.

Generative Sufficiency and Predictive Utility of the HMGPM

The current project intends to establish the generative sufficiency and predictive utility of the model. Establishing generative sufficiency involves ensuring that the HMGPM produces reasonable patterns of gain derivation based on its core variables and their proposed relationships. With confidence in its internal validity, the model's predictive utility can then be evaluated. The predictive utility of the HMGPM will be established via its ability to replicate empirically-observed and previously simulated patterns of multiple-goal pursuit. In addition, extensions of previous findings and new hypotheses within a hierarchical goal systems framework will be proposed.

The generative sufficiency stage will focus on the validity of the proposed relationships between superordinate need, subordinate discrepancy, and instrumentalities. The predictive utility stage will focus on the ability of the HMGPM to replicate and generate extensions of patterns of multiple-goal pursuit observed in the literature. The following are predictions under specified conditions of instrumentality strength and equality, goal configuration (Figure 6), superordinate goal need strength and equality, and likelihood of goal progress that, if supported, will demonstrate the validity of the model.

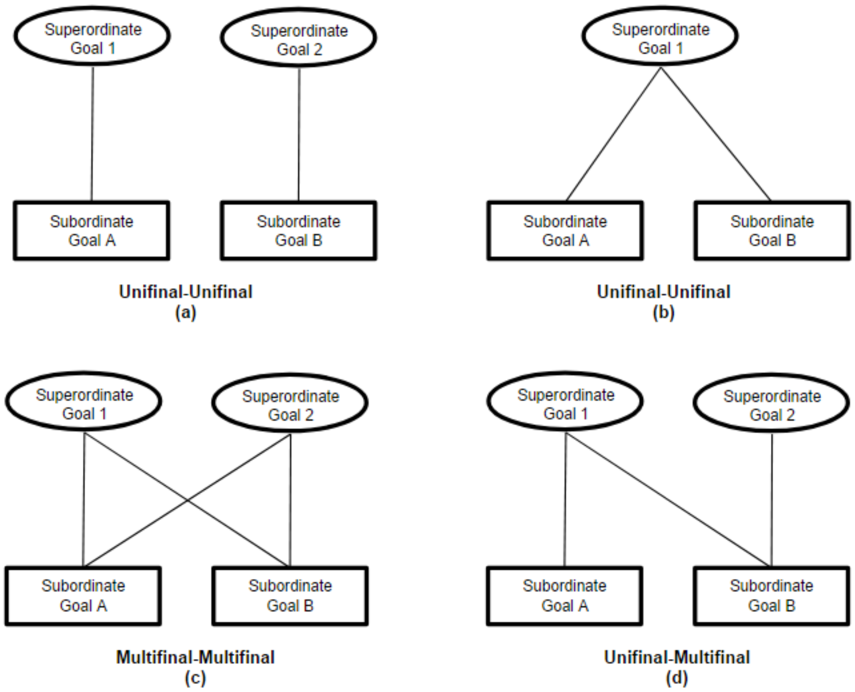

Figure 6. Goal configurations. Configuration (a) represents a unifinal-unifinal system, where each unifinal subordinate goal is connected to a unique superordinate goal. Configuration (b) represents a unifinal-unifinal system where both unifinal subordinate goals are connected to the same superordinate goal. Configuration (c) represents a multifinal-multifinal system, in which both subordinate goals are connected to both superordinate goals. Configuration (d) represents a unifinal-multifinal system, where one subordinate goal is connected to a single superordinate goal, shared with another subordinate goal with an additional connection to an alternative superordinate goal.

Generative Sufficiency

The internal validity of the HMGPM will first be established to ensure that the specified processes produce reasonable and theoretically-expected patterns of gain derivation and multiple-goal pursuit. The following predictions will focus on demonstrating the connections between 1) subordinate discrepancy reduction and superordinate need, and 2) superordinate perceived importance and subordinate gain, both via instrumentality.

Subordinate Discrepancy and Superordinate Need. While both superordinate goal need and subordinate goal discrepancy represent distances from a desired state, they are conceptually different. Subordinate discrepancy is a motivational force unique to a single subordinate goal, in that its value does not influence alternative subordinate goals in a goal system. Further, it is reduced as a direct result of successful goal pursuit. Superordinate need, on the other hand, impacts all connected subordinate goals (via the derivation of gain) and is only reduced to the extent that an individual perceives the pursuit of a subordinate goal to impact the state of higher-level goals. As discussed above, the strength of this perceived connection is captured by the instrumentality component of the HMGPM, which scales any progress made at the subordinate level and transfers it to connected subordinate goals' needs. This conceptual difference between superordinate need and subordinate discrepancy and their relationship to one another via instrumentality will be demonstrated in the generative sufficiency stage of the current project.

Prediction 1: Superordinate need will decrease as a function of subordinate discrepancy reduction at a faster rate at higher levels of instrumentality.

Perceived Importance and Gain. The HMGPM proposes that a goal's value (i.e., gain) is derived from its connection to higher order goals. Similar to the upward transfer of subordinate discrepancy to superordinate need, the perceived importance of superordinate goals is transferred down to connected lower order goals such that a subordinate goal's gain is equal to the sum of all connected superordinate goals' perceived importance scaled by each connection's instrumentality (equation 9). This relationship between superordinate perceived importance and subordinate gain via instrumentality will be demonstrated in establishing the model's generative sufficiency.

If instrumentality is held constant across subordinate-superordinate connections in a goal system, subordinate gain will be a direct function of superordinate perceived importance. In a unifinal-unifinal or multifinal-multifinal configuration, this implies that if two subordinate goals are connected to the same superordinate goal or different superordinate goals with equal perceived importance, they will each derive the same gain from the superordinate level.

Prediction 2: Two unifinal subordinate goals will have equal gain when connected to different superordinate goals with equal perceived importance or to the same superordinate goal.

Prediction 3: Two multifinal subordinate goals will have equal gain when connected to superordinate goals with equal perceived importance.

If superordinate perceived importance is unequal, different patterns of gain derivation are expected in the unifinal-unifinal and multifinal-multifinal configurations. In the multifinal-multifinal configuration, because both subordinate goals are connected to the superordinate level with equal instrumentality, they derive the same gain whether the goals at the superordinate level have equal or unequal perceived importance. In the unifinal-unifinal configuration, the two subordinate goals derive their gain from unique sources. Thus, as long as their instrumentality to the superordinate level is equal, the unifinal subordinate goal connected to the superordinate goal with higher perceived importance will have a higher gain than the alternative unifinal subordinate goal.

Prediction 4: Two multifinal subordinate goals will have equal gain when connected to superordinate goals with unequal perceived importance.

Prediction 5: The unifinal subordinate goal connected to the superordinate goal with a higher perceived importance will have higher gain than the unifinal subordinate goal connected to an alternative superordinate goal.

Instrumentality and Gain. The previous section addressed the direct effect of superordinate perceived importance on gain derivation, independent of instrumentality. Because instrumentality determines the extent to which superordinate perceived importance transfers to a subordinate goal, it is also critical that its function be validated in establishing the generative sufficiency of the HMGPM.

In unifinal-unifinal and multifinal-multifinal configurations, if superordinate perceived importance is held constant (i.e., the goal system includes a single superordinate goal, such as in Figure 6b, or two superordinate goals such as in Figure 6a or 6dc with equal perceived importance), subordinate gain will be a direct function of instrumentality. This suggests that if subordinate goals have equal instrumentality to the superordinate goals, they will derive the same gain.

Prediction 6: Two unifinal subordinate goals with equal instrumentalities will have equal gain.

Prediction 7: Two multifinal subordinate goals with equal instrumentality sets will have equal gain.

If, however, two subordinate goals' instrumentalities to superordinate goals differ, a greater amount of superordinate perceived importance will transfer to the subordinate goal with the higher instrumentality (or instrumentality set, in the multifinal-multifinal configuration).

Prediction 8: The unifinal subordinate goal with a higher instrumentality will have higher gain than an alternative unifinal subordinate goal connected to the same or different superordinate goal.

Prediction 9: The multifinal subordinate goal with the higher instrumentality set will have higher gain than an alternative multifinal subordinate goal.

Predictive Utility

Once the generative sufficiency and internal validity of the HMGPM is established, its utility in explaining existing empirical findings and advancing new predictions for future research can be explored. By placing multiple-goal pursuit in a hierarchical framework, it is proposed that the model can be used to explain why goal switching is driven by expectancy near a deadline (Schmidt & Deshon, 2007; Vancouver et al., 2010) and when multifinal versus unifinal goals would be preferred (Kopetz et al., 2011; Kruglanski et al., 2013). It should also be capable of explicating dynamics of goal value during goal pursuit, such as the choice to pursue a goal despite a low expectancy of progress and the eventual equalization of the perceived importance of goals in an individual's goal network. These topics are discussed below.

Goal Switching. Schmidt and DeShon's (2007) findings and Vancouver et al.'s (2010) simulation results, where goal switching was first driven by discrepancy then expectancy, are expected in the current model, but only in specific goal configurations. In the scheduling paradigm used by these previous researchers, participants were faced with two mutually exclusive tasks between which they could allocate time: create schedules for students at ABC College or create schedules for students at XYZ College. In the current model, these two tasks represent subordinate goals. Though a superordinate goal for participants was not explicit in the original studies, the need to perform well enough to justify their earned research credit represents a plausible superordinate goal. Whatever the superordinate goal however, the defining feature of the experiment was that engaging in either subordinate goal (i.e., scheduling for either college) was equally as instrumental to the higher order goal. Consequently, the gain of each subordinate goal did not differ, meaning task choice was driven only by changes in discrepancy and expectancies at the subordinate goal level. In the current model, this same pattern would arise in cases where a single superordinate goal is connected to two subordinate goals (Figure 6b) with equal instrumentality, where the pursuit of either subordinate goal is mutually exclusive. More generally, this same pattern would be expected in the case of any number of superordinate goals as long as the instrumentality sets of all subordinate goals are equal.

> *Prediction 10: When subordinate goals are connected to a single or multiple superordinate goals with equal instrumentality, goal choice will initially favor the subordinate goal with the greatest discrepancy. As subordinate goals' expectancies diverge, goal choice will favor the subordinate goal with the greatest expectancy.*

An important extension permitted by the HMGPM is the ability to examine conditions where the perceived importance of superordinate goals is not equivalent and subordinate goals have different finalities (i.e., the unifinal-multifinal configuration, Figure 6d). In another study, Schmidt and DeShon (2007) provided a monetary incentive to which only one of the scheduling tasks was instrumental. This reward increased the amount of time participants allocated to this particular task over the alternative. If this monetary incentive is interpreted as a second, less focal superordinate goal to the superordinate goal of completing the study, this context can be modeled as a unifinal-multifinal configuration, where the superordinate goals to which the multifinal subordinate goal is instrumental have unequal perceived importance. While the unifinal subordinate goal derives its gain from the single superordinate goal, the multifinal subordinate goal derives additional gain from the second superordinate goal.

Prediction 11: A multifinal subordinate goal will have a higher gain than a unifinal subordinate goal if both subordinate goals are equally instrumental to the superordinate goal with the higher perceived importance, and goal choice will favor the multifinal subordinate goal.

The Value of Multifinality. Research suggests that an individual may prefer a subordinate goal with connections to many superordinate goals (i.e., a multifinal subordinate goal) or a subordinate goal connected to a single superordinate goal (i.e., a unifinal goal), depending on the perceived importance of superordinate goals (Kopetz et al., 2011; Kruglanski et al., 2013). This is an important factor in the study of multiple-goal pursuit, but has yet to be considered in the current models that integrate goal choice and self-regulation.

The influence of the number of superordinate goals is evident in Kopetz and colleagues' (2011) study of meal preferences. When a participant had the goal of getting lunch along with other goals to be completed that day (a multiple superordinate goal configuration), they preferred meals that were easier to get (i.e., a multifinal subordinate goal), allowing them to satisfy both the goal of getting lunch and to continue pursuing their other goals, whereas a unifinal meal would have only helped them attain the goal of getting lunch. The current model suggests this effect is representative of a goal system in which the superordinate goals vary on their perceived importance and the unifinal and multifinal subordinate goals are both connected to the superordinate goal with lower perceived importance (e.g., the goal of getting lunch in Kopetz et al., 2011). The lower perceived importance of the superordinate goal connected to the unifinal subordinate goal will result in that goal deriving less gain than the multifinal subordinate goal.

Prediction 12: A unifinal subordinate goal will have lower gain than a multifinal subordinate goal when it is instrumental to the superordinate goal with lower perceived importance, leading to goal choice favoring the multifinal subordinate goal.

Note that this effect should not be limited to the choice between a unifinal subordinate goal and a multifinal subordinate goal. In unifinal-unifinal and multifinal-multifinal configurations, the condition of unequal superordinate goal perceived importance and unequal instrumentalities suggests that as the perceived importance of one superordinate goal increases relative to others', the subordinate goal that is most instrumental to the most important superordinate goal is expected to be preferred. This effect was also demonstrated by Kopetz et al. (2011) in a multifinal-multifinal scenario – participants who perceived the superordinate goal of food enjoyment as more important than the superordinate goal of dieting chose foods based on their tastiness (more instrumental to the goal of food enjoyment) rather than their caloric content. In other words, the different food choice options (i.e., subordinate goals) were multifinal. All food choices equally satisfied the need for a meal (superordinate goal 1); however, one food choice was more instrumental to satisfying the need for tastiness (superordinate goal 2) than for dieting (superordinate goal 3), and the other food choice was more instrumental to satisfying the need to diet than for tastiness. For individuals who perceived tastiness as more important relative to dieting, the multifinal subordinate goal most instrumental to that superordinate goal was favored.

Prediction 13: The subordinate goal with the higher instrumentality to the superordinate goal with the higher perceived importance will have a higher gain and be favored in goal choice over an alternative subordinate goal in unifinal-unifinal and multifinal-multifinal configurations.

Unrealistic Optimism. At times, individuals pursue a goal despite a low likelihood of attaining it. This may be due to the exaggerated value of a goal. Take, for example, a professor with a high need to display competency in research and with little interest in teaching. They may have a subordinate goal to publish three papers by the end of the summer, but also to prepare enough for the Fall semester to receive a positive teaching rating. Because of the greater importance they place on the superordinate research goal, they will likely focus on the more instrumental subordinate goal of publishing papers. The expectancy of publishing three papers decreases as the summer months pass, but the professor stays unrealistically optimistic due to the high perceived importance of the superordinate research goal. If this high perceived importance counteracts low expectancy and the professor focuses on publishing papers, preparation for their fall classes may be neglected. The gain of publishing overrides any decreases in expectancy that otherwise motivate goal-disengagement, to the detriment of the alternative teaching goal.

In the context of the HMGPM, this unrealistic optimism in the face of low expectancy is likely to happen when a subordinate goal derives high levels of gain (via high instrumentality) from a superordinate goal with high perceived importance. Further, this is especially likely when the pursuit of the subordinate goal is difficult (i.e., there is a low rate of success) because the need of the superordinate goal is not reduced, keeping the subordinate goal's derived gain high.

Prediction 14: A subordinate goal with high instrumentality to a superordinate goal with high perceived importance will be favored to an alternative subordinate goal in goal choice when goal pursuit is unsuccessful, even at low levels of expectancy.

Equalization of Superordinate Perceived Importance. In the existing empirical literature, little attention has been paid to the effect of goal choice and pursuit on higher-order goals in an individual's goal network. The effect of subordinate discrepancy reduction on superordinate perceived importance, discussed in the generative sufficiency section above, addresses the relationship between a single subordinate goal and a single superordinate goal. The HMGPM can also be used to advance the understanding of the dynamics of a goal system that includes multiple subordinate and superordinate goals. Specifically, an interesting side effect of the correlation between subordinate goal progress and superordinate need reduction is that the needs of two superordinate goals may equalize over time as connected subordinate goals are pursued. If one superordinate goal has a higher need, the subordinate goal with the higher instrumentality to that superordinate goal will derive more gain and therefore be favored in goal choice to an alternative subordinate goal. Progress made on the subordinate goal is transferred back up to the superordinate goal, decreasing its need toward the level of need of the alternative superordinate goal.

However, the equalizing of superordinate goal perceived importance is not expected in the unifinal-multifinal condition where the multifinal and unifinal subordinate goals have equal instrumentalities to the superordinate goal with the highest perceived importance. Though the multifinal subordinate goal is expected to be favored, the decrease in the need of the most important superordinate goal influences the gain of the unifinal subordinate goal to the same extent it influences the gain of the multifinal subordinate goal. In other words, the relative difference between the two subordinate goals' gains derived from the most important superordinate goal is maintained. To summarize:

Prediction 15: In unifinal-unifinal or multifinal-multifinal conditions, as the subordinate goal with the highest instrumentality to the superordinate goal with the highest perceived importance is chosen more often over time, superordinate needs will equalize.

Methods

The HMGPM was translated into computer code in order to evaluate its generative sufficiency and predictive validity via virtual experimentation and simulation (Vancouver & Weinhardt, 2012; Kozlowski, Chao, Grand, Braun, & Kuljanin, 2013; Grand, Braun, Kuljanin, Kozlowski, & Chao, 2016). The virtual experimentation involved systematically manipulating the values of core parameters of the model to represent its theoretical space and to explore the 15 predictions presented above. The model was simulated, or allowed to run over multiple time periods, within the specified conditions to examine the extent to which the dynamics of the model result in theoretically expected and conceptually reasonable patterns of goal pursuit and goal choice.

Description of Simulation

Table 1 provides the algorithm of the HMGPM. In brief, each simulation cycles between updating superordinate level characteristics based on goal progress via equation 10, deriving subordinate level gain via equation 9 and expected utilities via equations 1 through 6, and determining which subordinate goal to pursue at each decision point via equations 7 and 8. The simulation ends when the deadline has been reached or both subordinate goals' have been attained (i.e., their discrepancies equal 0), whichever occurs first.

In the current simulations, the deadline was set to 50 "time units," except where otherwise noted. The expected lag (i.e., the amount of time required to attempt to accomplish a single unit of one subordinate goal, α) was set to 2. The reference (g) for each subordinate goal was set to 25. Time sensitivity (γ) was randomly sampled from a normal distribution with a mean of 0.33 and a standard deviation of 0.25, restricted to be a positive value. These time sensitivity parameters were estimated by Ballard and colleagues (2016) in a similar simulation study to the current one, based on a previous empirical study of multiple goal-pursuit (Ballard, Yeo, Vancouver, & Neal, 2013). Holding time sensitivity constant, this combination of deadline, expected lag, and reference resulted in each simulation beginning with a 50% expectancy of attaining either subordinate goal, based on equation 3.

Table 1
HMGPM Algorithm

Step	Action
1	Initialize time clock $T = 0$
2	Update each subordinate goal's discrepancy
3	Update each superordinate goal's need
4	Calculate each subordinate goal's gain, valence, expectancy, and expected utility
5	Calculate the motivational value of each consequence
6	Sample the momentary attractiveness of each subordinate goal using their respective attention weights for each consequence
7	Subtract the momentary attractiveness of subordinate goal 2 from that of subordinate goal 1, add to preference (P)
8	If $-\theta < P < \theta$, return to Step 6
9	If $P < -\theta$, pursue subordinate goal 2, or if $P > \theta$, pursue subordinate goal 1
10	Sample the consequence realized using the attention weights of each consequence associated with the subordinate goal chosen to be pursued
11	Update the current state of each subordinate goal based on the consequence realized
12	Update $T = T + \alpha$
13	If $d_1 \neq 0$ or if $d_2 \neq 0$ or if $T <$ deadline, return to Step 2
14	End

Note. T = time period. R code for computational model and simulation provided in Appendices A and B.

Preference threshold (θ) was randomly sampled from a normal distribution with a mean of 0.30 and a standard deviation of 0.50. Given the subordinate reference values of 25 and the range of superordinate need values (n) used in the virtual experimentation (Table 3), described below, these parameter values allowed for both a sufficient and reasonable number of preference accumulations in Steps 6 through 8 before a subordinate goal was chosen to be pursued. The value drawn was positive for subordinate goal 1, determining the upper preference threshold, and negative for subordinate goal 2, determining the lower preference threshold. While the model can accommodate avoidance goals, the current predictions focus on approach goals. Thus, all subordinate goals were approach goals, meaning their intercepts (b) in the calculation of valence (v) were equal to 0 and their gains (κ) were positive.

Description of Virtual Experimentation

As with the MGPM and MGPM*, the HMGPM contains a number of free parameters that could potentially be manipulated. To systematically manipulate each of these parameters in a fully-crossed virtual experiment would be infeasible and unwieldy. Fortunately, such an approach is not needed to test the specific predictions of this study. Instead, 18 unique conditions were created that manipulated the critical parameter values of interest for evaluating the propositions described above (Table 2). These conditions were created by combining specific consequence attention weight (w) schemes, goal configurations, superordinate perceived importance, and instrumentality (c) sets representative of the goal pursuit contexts of interest.

Table 2

Simulated Conditions of the HMGPM

Condition	Prediction	Attention Weight (w) Scheme	No. of Super. Goals	Super. Needs (n)	Sub. Finality	c_{11}	c_{12}	c_{21}	c_{22}
1	1	Typical	2	Equal	U-U	Low	-	-	Low
2	1, 2, 6	Typical	2	Equal	U-U	Mod.	-	-	Mod.
3	1	Typical	2	Equal	U-U	High	-	-	High
4	2, 5	Typical	1	-	U-U	Mod.	-	Mod.	-
5	3, 7	Typical	2	Equal	M-M	Mod.	Mod.	Mod.	Mod.
6	4	Typical	2	Unequal	M-M	Mod.	Mod.	Mod.	Mod.
7	5, 14	Typical	2	Unequal	U-U	Mod.	-	-	Mod.
8	8	Typical	2	Equal	U-U	High	-	-	Mod.
9	8	Typical	1	-	U-U	High	-	Mod.	-
10	9	Typical	2	Equal	M-M	High	High	Mod.	Mod.
11	10	Mutually Exclusive	1	-	U-U	Mod.	-	Mod.	-
12	10	Mutually Exclusive	2	Equal	U-U	Mod.	-	-	Mod.
13	10	Mutually Exclusive	2	Equal	M-M	Mod.	Mod.	Mod.	Mod.
14	11	Typical	2	Unequal	U-M	Mod.	-	Mod.	Mod.
15	12	Typical	2	Unequal	U-M	-	Mod.	Mod.	Mod.
16	13, 15	Typical	2	Unequal	M-M	High	Mod.	Mod.	Mod.
17	14	Low Progress	2	Highly Unequal	U-U	High	-	-	Mod.
18	15	Typical	2	Unequal	U-U	High	-	-	Mod.

Note. Predictions describe which study prediction the associated condition was created to examine. U = unifinal; M = multifinal; c_{kh} = instrumentality of subordinate goal k to superordinate goal h

The consequence attention weight schemes reflected three scenarios: what will be referred to as a "typical" scheme; a mutually exclusive goal pursuit scheme; and a low likelihood of progress scheme. In the typical scheme, the most likely consequence of pursuing a subordinate goal was succeeding at attaining the goal chosen to be pursued (i.e., reducing its discrepancy by 1 unit) and failing to attain the alternative goal. The least likely consequence was failing at attaining the chosen goal and succeeding at attaining the alternative goal. In the mutually exclusive goal pursuit scheme, there was 0% chance of succeeding at attaining both subordinate goals and an 80% chance of succeeding at attaining the chosen goal. In the low likelihood of progress scheme, there again was 0% chance of succeeding at attaining both subordinate goals, but only a 20% chance of succeeding at attaining the chosen goal. See Table 3 for further details.

Table 3

Consequence Attention Weight Schemes

Typical

Prioritize Goal 1	Goal 2 Success	Goal 2 Failure
Goal 1 Success	0.20	0.65
Goal 1 Failure	0.05	0.10
Prioritize Goal 2	Goal 2 Success	Goal 2 Failure
Goal 1 Success	0.20	0.05
Goal 1 Failure	0.65	0.10

Mutually Exclusive

Prioritize Goal 1	Goal 2 Success	Goal 2 Failure
Goal 1 Success	0	0.80
Goal 1 Failure	0	0.20
Prioritize Goal 2	Goal 2 Success	Goal 2 Failure
Goal 1 Success	0	0
Goal 1 Failure	0.80	0.20

Low Likelihood of Progress

Prioritize Goal 1	Goal 2 Success	Goal 2 Failure
Goal 1 Success	0	0.20
Goal 1 Failure	0.80	0
Prioritize Goal 2	Goal 2 Success	Goal 2 Failure
Goal 1 Success	0	0
Goal 1 Failure	0.20	0.80

Note. Values represent the probability of one of four outcomes based on the subordinate goal chosen to be pursued. Success implies discrepancy is reduced by 1 unit. Failure implies discrepancy is not reduced.

The goal configurations were one of the four configurations presented in Figure 6, depending on the prediction. Superordinate perceived importance was manipulated via the relative needs of the superordinate goals within the goal system. In conditions in which there was a single superordinate goal or two superordinate goals with equal perceived importance, the superordinate goal needs were set equal to 25. The alternative conditions involved two superordinate goals with unequal needs (n_1 = 25, n_2 = 15) or highly unequal needs (n_1 = 30, n_2 = 5).

A subordinate goal's instrumentality to a superordinate goal was set at one of three values, depending on the condition: Low (c = 0.1), moderate (c = 0.5), or high (c = 1.0). With the exception of conditions 1 and 3, which were specifically designed to address *P1* (the relationship between instrumentality, superordinate need, and subordinate discrepancy), the moderate instrumentality was used across all connections in conditions of equal instrumentality. In conditions of unequal instrumentality, combinations of high and moderate instrumentalities were used.

Fifty simulations were run in each condition. Subordinate goal discrepancy, gain, valence, expectancy, and expected utility, superordinate goal need, and subordinate goal choice were collected at each decision point in each simulation. The percentage of simulations that chose to pursue subordinate goal 1 at each decision point within each condition served as the final goal choice variable, all others were averaged across simulations at each decision point within each condition.

Results

Generative Sufficiency

The following results evaluate the validity of the logic put forth by the HMGPM. The generative sufficiency of the model examined the core concepts of subordinate discrepancy, subordinate gain, superordinate need, and instrumentality, and their relationships to one another. Except where noted, plots represent the outcome of interest averaged across the 50 simulations at each decision point.

Subordinate Discrepancy and Superordinate Need. Superordinate need was predicted to decrease as a function of subordinate discrepancy at an increasing rate at higher levels of instrumentality (*P1*). Figure 7a represents the discrepancy of three different subordinate goals across decision points. Because these subordinate goals existed within goal configurations that were identical besides their instrumentality, their discrepancies decreased at equal rates. However, because their instrumentalities to the superordinate goal were unequal, the rate at which the superordinate goal's need decreased as discrepancy decreased also differed (Figure 7b). This rate was highest at the highest level of instrumentality ($c = 1.0$, i.e., a direct relationship, where superordinate need decreased by one unit when discrepancy decreased by one unit). This rate was lowest at the lowest level of instrumentality ($c = 0.1$, where superordinate need decreased by 0.1 units as discrepancy reduced by one unit).

These results support the process suggested by the HMGPM whereby subordinate goal pursuit is transferred to the superordinate level via instrumentality. While the discrepancy of three different subordinate goals reduces at an identical rate as those goals are pursued with success (Figure 7a), the extent to which higher-order superordinate goals are met is a function of instrumentality, such that higher instrumentalities transfer more subordinate goal progress to

(a)

(b)

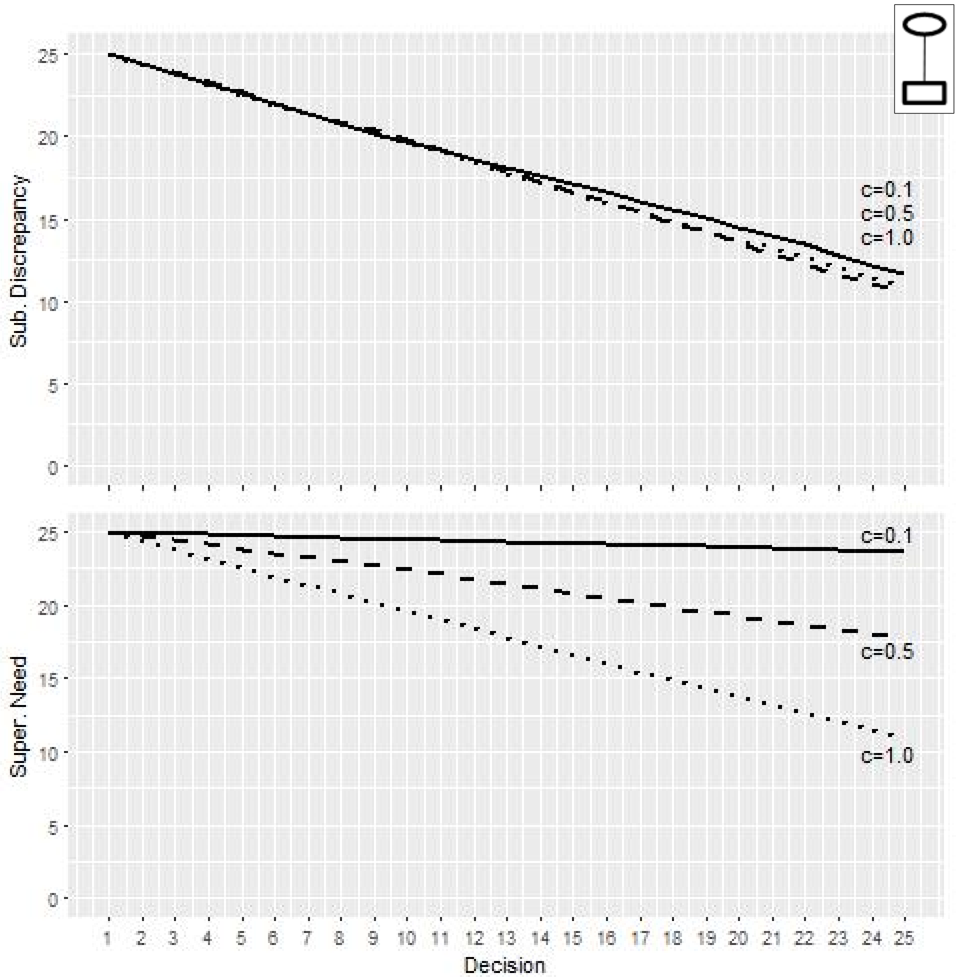

Figure 7. Subordinate discrepancy and superordinate need. Figure 7a represents the discrepancy of 3 unifinal subordinate goals across decision points. Figure 7b represents the need of the 3 superordinate goals connected to the 3 subordinate goals at different levels of instrumentality across decision points.

their connected superordinate goals (Figure 7b). In other words, the attainment of a higher-order goal is a function of the extent to which an individual perceives a lower-order goal to be instrumental in doing so.

Perceived Importance and Gain. Subordinate goal gain was predicted to be a function of superordinate goal perceived importance, independent of instrumentality. As discussed in the description of the simulation and experimentation, perceived importance was manipulated via superordinate need. When two unifinal subordinate goals are connected to the same superordinate goal or to two different superordinate goals with equal need, they were predicted to have equal gain (*P2*). Figures 8a and 8b represent a unifinal-unifinal configuration, where both

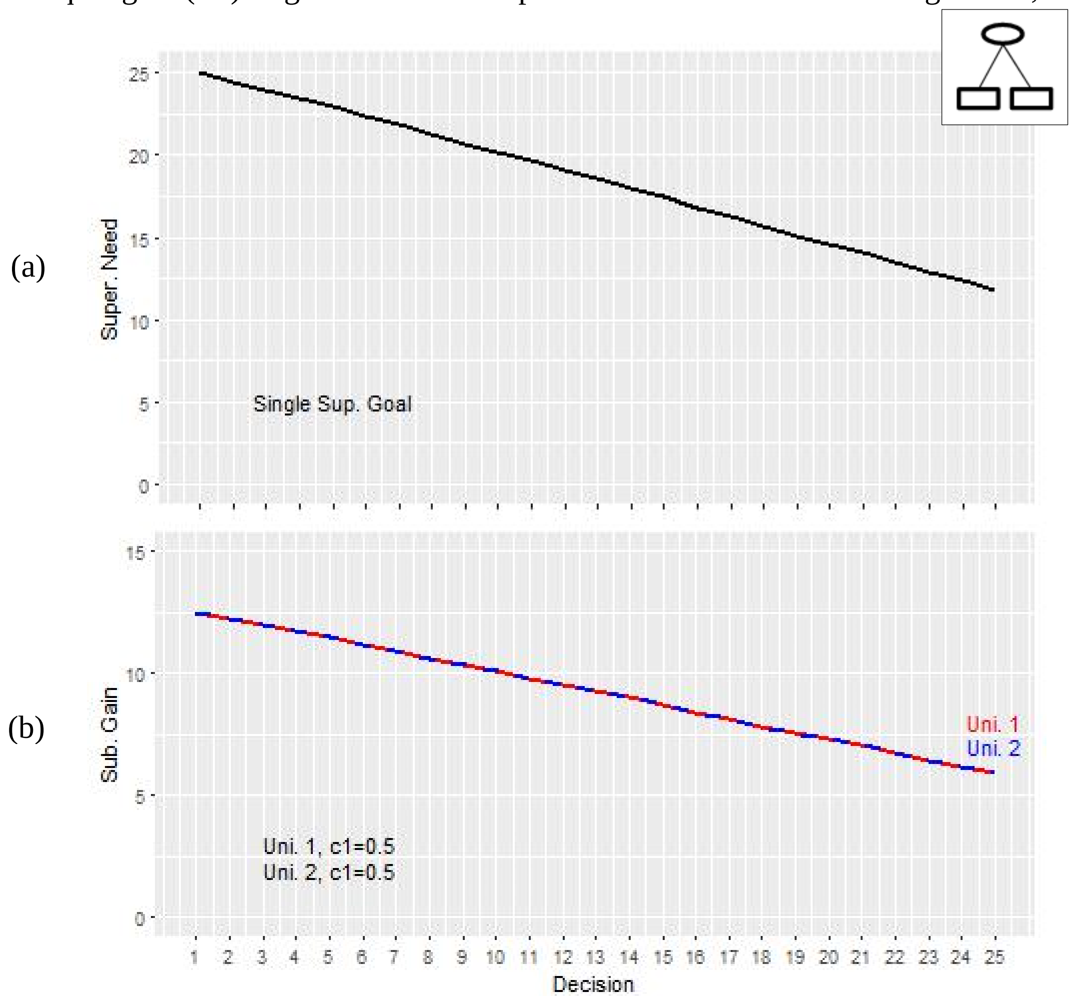

Figure 8. Perceived importance and gain, unifinal-unifinal, single superordinate goal. c_h=instrumentality to superordinate goal h; Figure 8a represents the need of a single superordinate goal across decisions, to which both unifinal subordinate goals in Figure 8b are connected with equal instrumentality. Figure 8b represents the derived gain of these two unifinal subordinate goals across decisions.

unifinal subordinate goals are connected to the same superordinate goal. The subordinate goals derive their gain from the same superordinate goal, and their gains decrease at an equal rate as the superordinate need decreases.

Figures 9a and 9b represent the latter configuration, where two unifinal subordinate goals are connected to different superordinate goals with equal need. Though each subordinate goal derives its gain from different superordinate goals, these superordinate goals' needs do not differ and equal amounts of superordinate need are transferred to the subordinate goals.

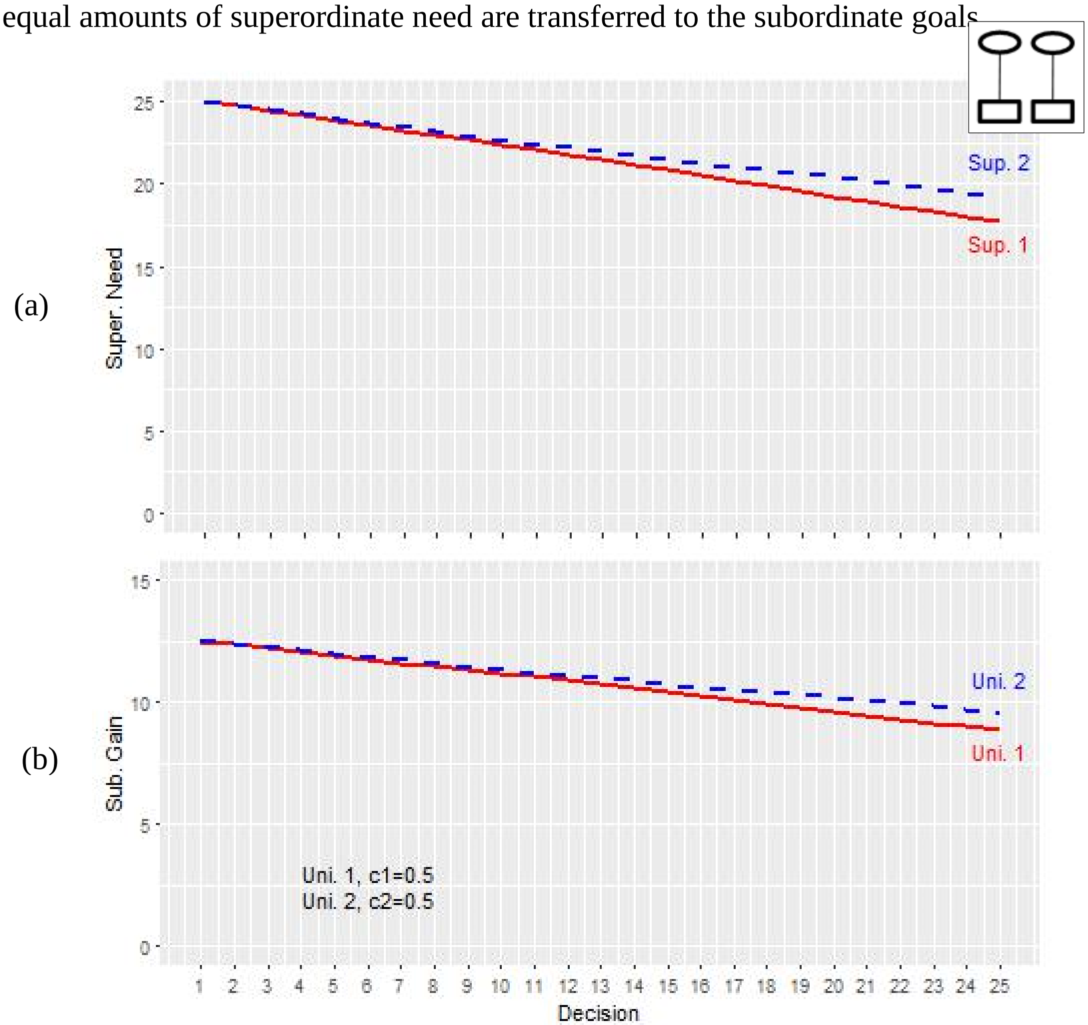

Figure 9. Perceived importance and gain, unifinal-unifinal, two equal superordinate goals. c_h=instrumentality to superordinate goal h; Figure 9a represents the need of two superordinate goals across decisions. Figure 9b represents the derived gain of two unifinal subordinate goals across decisions. Unifinal subordinate goal 1 is connected to superordinate goal 1 and unifinal subordinate goal 2 is connected to superordinate goal 2.

It was also predicted that two multifinal subordinate goals would have equal gain when connected to superordinate goals with equal need (*P3*). Figures 10a and 10b represent this configuration. Because both multifinal subordinate goals derive their gain from the same superordinate goals, their gains do not differ and they decrease at equal rates as the superordinate needs decrease.

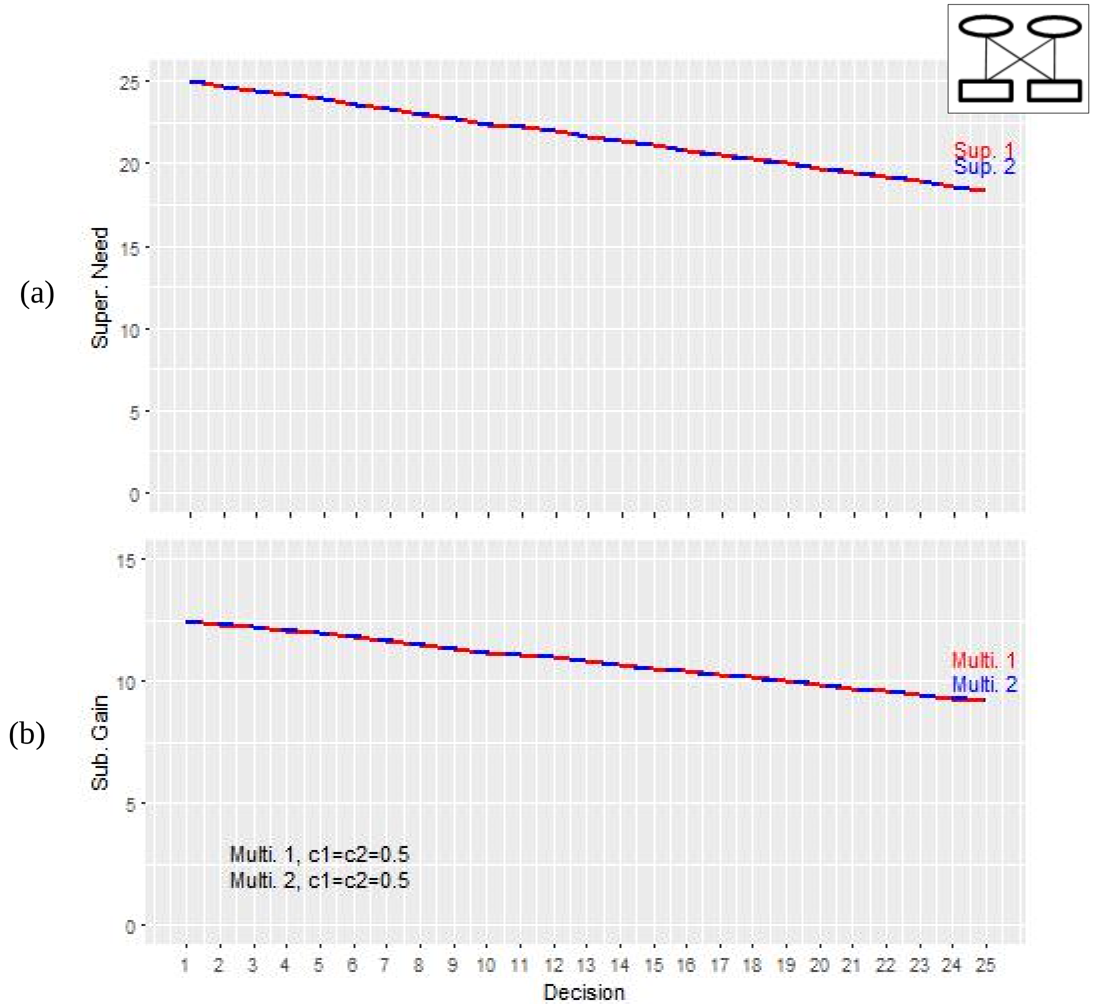

Figure 10. Perceived importance and gain, multifinal-multifinal, equal superordinate goals. c_h=instrumentality to superordinate goal *h*; Figure 10a represents the need of two superordinate goals across decisions. Figure 10b represents the derived gain of two multifinal subordinate goals across decisions. Both multifinal subordinate goals have equal instrumentalities to both superordinate goals.

Two multifinal subordinate goals' gains were not predicted to differ if their connected superordinate goals' needs did not differ (*P4*). Figures 11a and 11b represent this configuration. While superordinate goal 1 has a higher need than superordinate goal 2 across decisions (Figure 12a), multifinal subordinate goal 1 and multifinal subordinate goal 2 derive their gains from both goals, and thus their gains do not differ across decisions.

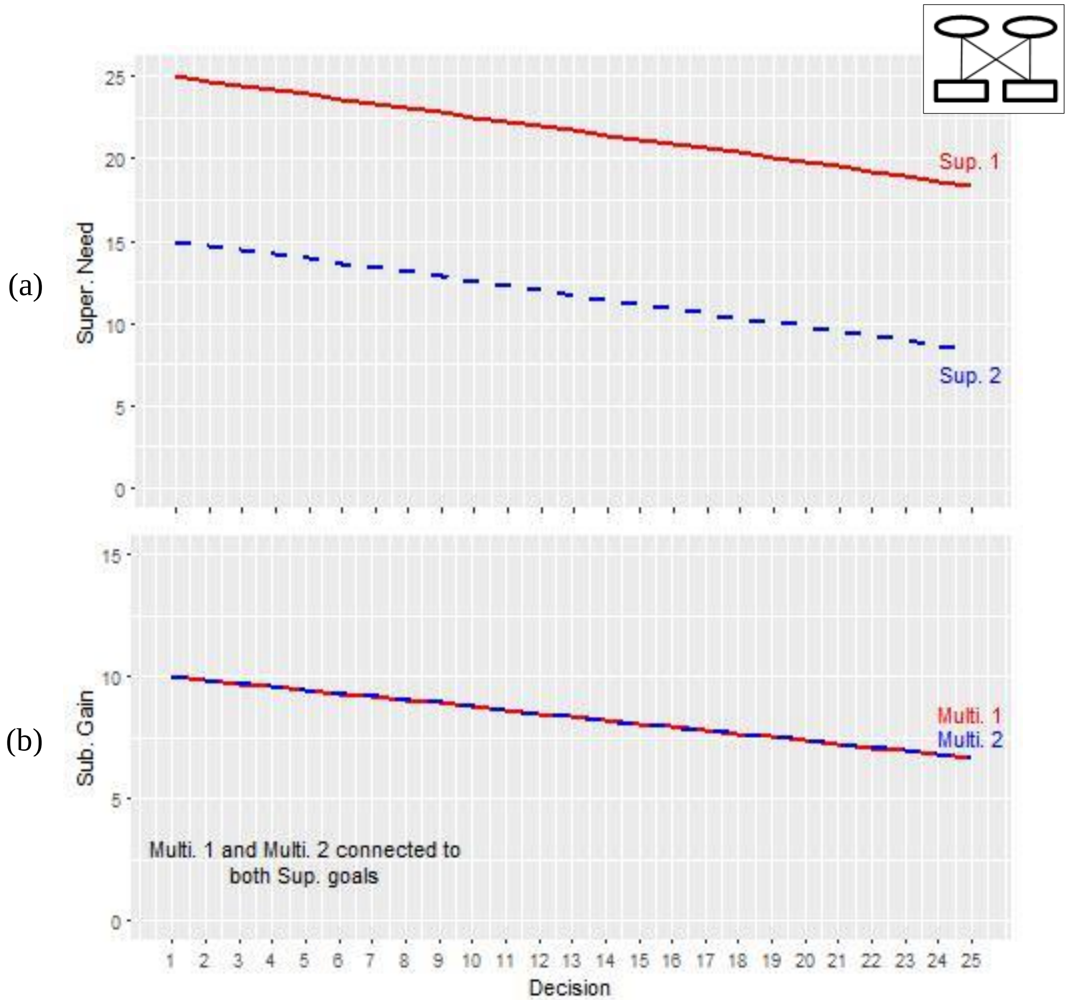

Figure 11. Perceived importance and gain, multifinal-multifinal, unequal superordinate goals. Figure 11a represents the need of two superordinate goals across decisions. Figure 11b represents the gain of the multifinal subordinate goals connected to the two superordinate goals, across decisions.

In the unifinal-unifinal configuration, however, unequal superordinate need was predicted to result in unequal subordinate gain (*P5*). Specifically, the unifinal subordinate goal connected to the superordinate goal with the higher need was expected to have a higher gain than the alternative unifinal subordinate goal. Figures 12a and 12b represent this configuration. Superordinate goal 1 has a higher need than superordinate goal 2. Because unifinal subordinate goal 1 is connected to superordinate goal 1, it has a higher derived gain than unifinal subordinate goal 2, which is connected to the alternative superordinate goal 2. Because their instrumentalities are held constant, the subordinate goal gains decrease at the same rate such that subordinate goal 1 has a higher gain than subordinate goal 2 across decisions.

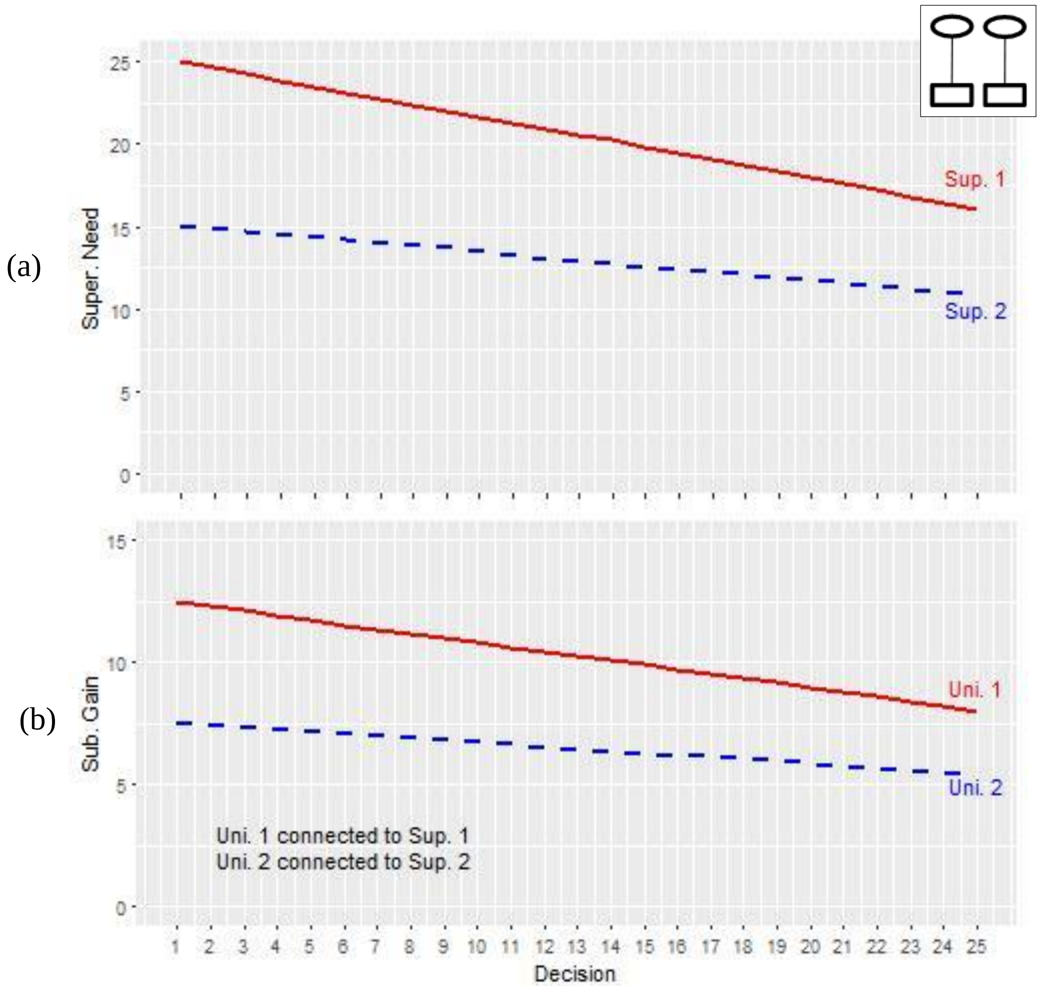

Figure 12. Perceived importance and gain, unifinal-unifinal, two unequal superordinate goals. Figure 12a represents the need of two superordinate goals across decisions, where superordinate goal 1 has a higher initial need than superordinate goal 2. Figure 12b represents the gain of the two unifinal subordinate goals connected to the two superordinate goals across decisions.

In sum, these patterns of gain derivation demonstrated above support predictions 2 through 5, and demonstrate that the conceptual relationship proposed to exist between superordinate perceived importance and subordinate gain is operationalized as intended in the HMGPM. When instrumentality is held constant, subordinate goals have equal gain when the superordinate goals to which they are connected are perceived to be equally as important. Further, if the subordinate goals are multifinal, they have equal gain even if the one superordinate goal is perceived to be more important than another, because they derive their gain from the same source. Only when two subordinate goals derive their gain from unique superordinate goals and one of those superordinate goals is perceived to be more important do the subordinate goals' gains differ. In other words, an individual perceives a lower-order goal to have higher value (i.e., gain) when it is connected to a higher-order goal that is more important than other higher-order goals and not connected to other lower-order goals.

Instrumentality and Gain. The previous section addressed the relationship between superordinate perceived importance and subordinate gain, holding instrumentality constant. Subordinate gain was also predicted to be a function of instrumentality, holding perceived importance (i.e., need) constant. If two subordinate goals in a unifinal-unifinal configuration or multifinal-multifinal configuration are equally as instrumental to the superordinate level, their gains were not predicted to differ (*P6* and *P7*). Figures 13a and 13b represent a unifinal-unifinal configuration where both unifinal subordinate goals are equally as instrumental to a single superordinate goal. Because their instrumentalities are equal, both subordinate goals derive equal gain from the superordinate goal, and their gains decrease at the same rate across decisions.

This pattern is also expected when the unifinal subordinate goals are connected to different superordinate goals with different needs. Figures 14a and 14b represent this configuration. Because the two unifinal subordinate goals have equal instrumentality to the superordinate level, their gains are equal and decrease at equal rates across decisions.

Similarly, when two multifinal subordinate goals have equal sets of instrumentalities to the superordinate level, their gains were predicted to be equal. Figures 15a and 15b represent a configuration in which two multifinal subordinate goals are connected to the same two superordinate goals with equal instrumentality. Because the degree of transfer between the superordinate and subordinate level is equal between the multifinal subordinate goals, their gains do not differ and they decrease at the same rate across decisions.

(a)

(b)

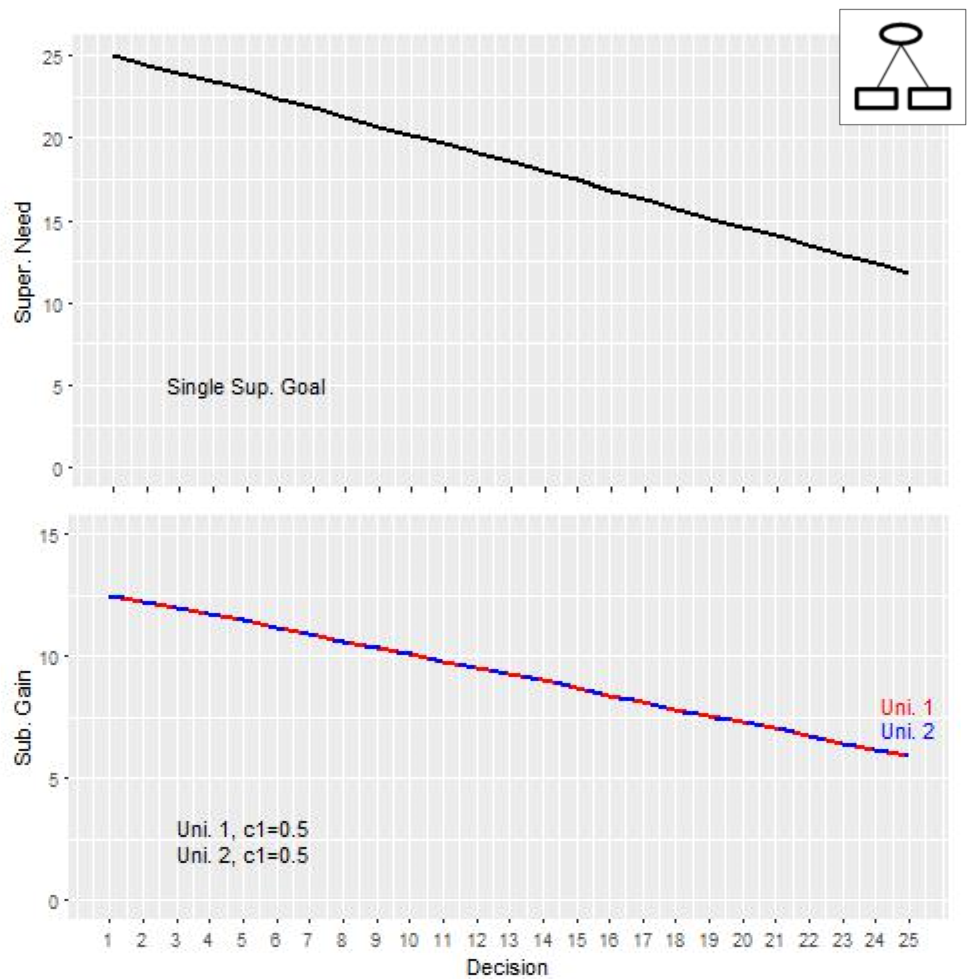

Figure 13. Instrumentality and gain, unifinal-unifinal, equal instrumentality, single superordinate goal. c_h=instrumentality to superordinate goal *h*; Figure 13a represents the need of a single superordinate goal across decisions, to which both unifinal subordinate goals in figure 13b are connected with equal instrumentality. Figure 13b represents the derived gain of these two unifinal subordinate goals across decisions.

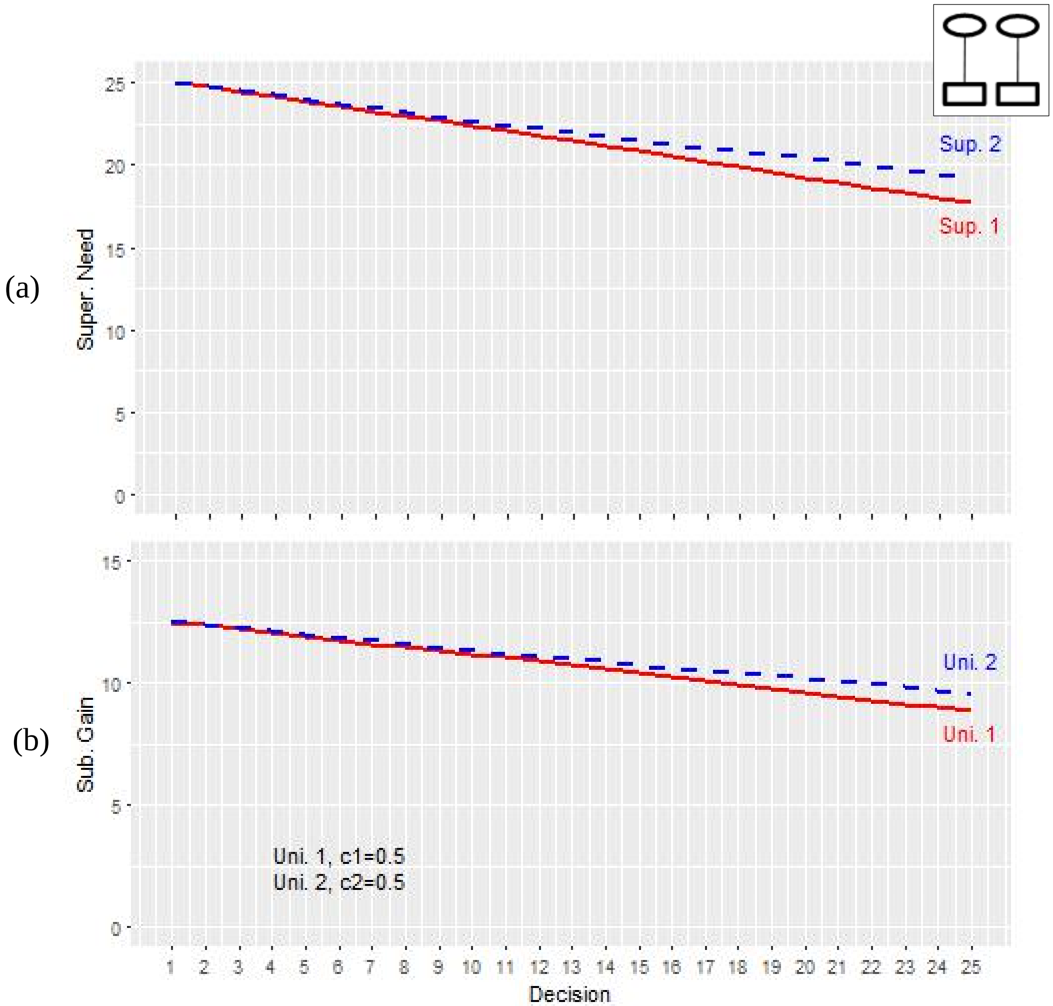

Figure 14. Instrumentality and gain, unifinal-unifinal, equal instrumentality, two superordinate goals. c_h=instrumentality to superordinate goal *h*; Figure 14a represents the need of two superordinate goals across decisions. Figure 14b represents the derived gain of two unifinal subordinate goals across decisions. Unifinal subordinate goal 1 is connected to superordinate goal 1 and unifinal subordinate goal 2 is connected to superordinate goal 2 with equal instrumentalities.

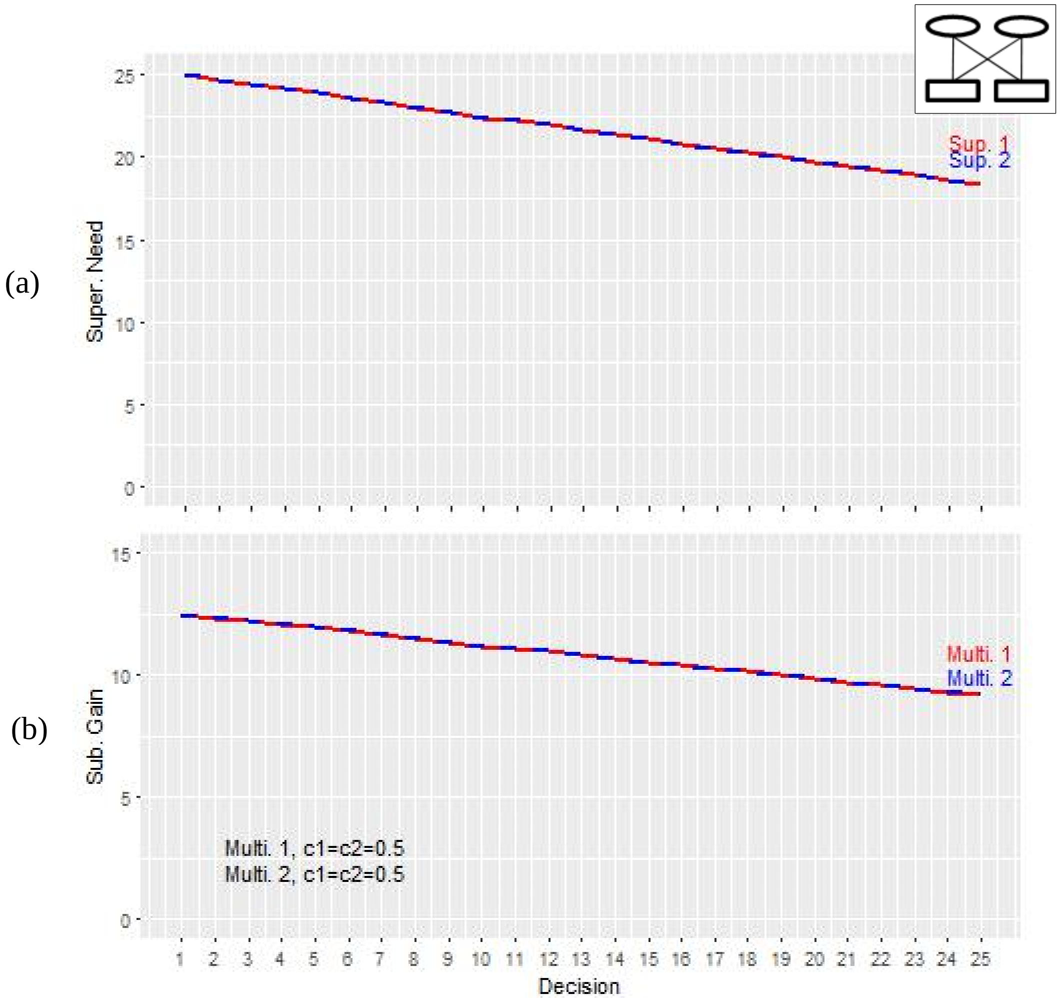

Figure 15. Instrumentality and gain, multifinal-multifinal, equal instrumentality. c_h=instrumentality to superordinate goal *h*; Figure 15a represents the need of two superordinate goals across decisions. Figure 15b represents the derived gain of two multifinal subordinate goals across decisions. Both multifinal subordinate goals have equal instrumentalities to both superordinate goals.

Subordinate goals were expected to have different gains if their instrumentalities differ. Specifically, it was predicted that if two unifinal subordinate goals were connected to the same superordinate goal or two different superordinate goals, the unifinal subordinate goal with the higher instrumentality would have a higher gain than the alternative unifinal subordinate goal (*P8*). Figures 16a and 16b represent the single superordinate goal configuration, where unifinal subordinate goal 1 has a high instrumentality with the superordinate goal and unifinal subordinate goal 2 has a moderate instrumentality. Because of the higher degree of transfer across its connection with the superordinate goal, subordinate goal 1 has a higher gain than

(a)

(b)

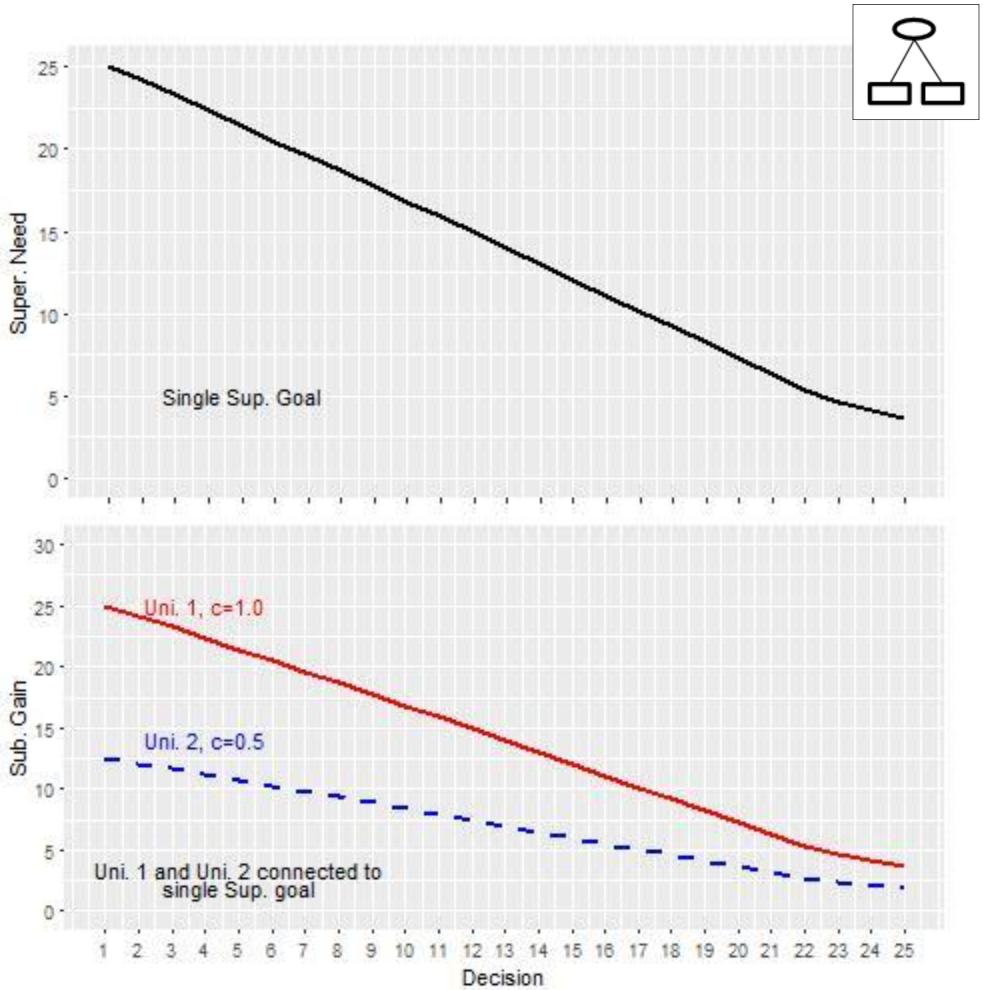

Figure 16. Instrumentality and gain, unifinal-unifinal, unequal instrumentality, single superordinate goal. *c*=instrumentality. Figure 16a represents the need of a superordinate goal across decisions. Figure 16b represents the gain of two unifinal subordinate goals connected to the superordinate goal in Figure 16a, across decisions. Unifinal subordinate goal 1 has a higher instrumentality to the superordinate goal than unifinal subordinate goal 2.

subordinate goal 2, and its gain decreases at a faster rate compared to that of subordinate goal 2 as the superordinate goal's need decreases.

Figures 17a and 17b represent the alternative unifinal-unifinal configuration with two superordinate goals. In Figure 17a, the two superordinate goals begin with the same need. Because of its higher instrumentality, unifinal subordinate goal 1 derives higher gain than unifinal subordinate goal 2. Because of its higher gain, unifinal subordinate goal 1 is pursued more frequently than unifinal subordinate goal 2 and, as discussed in the previous section on

(a)

(b)

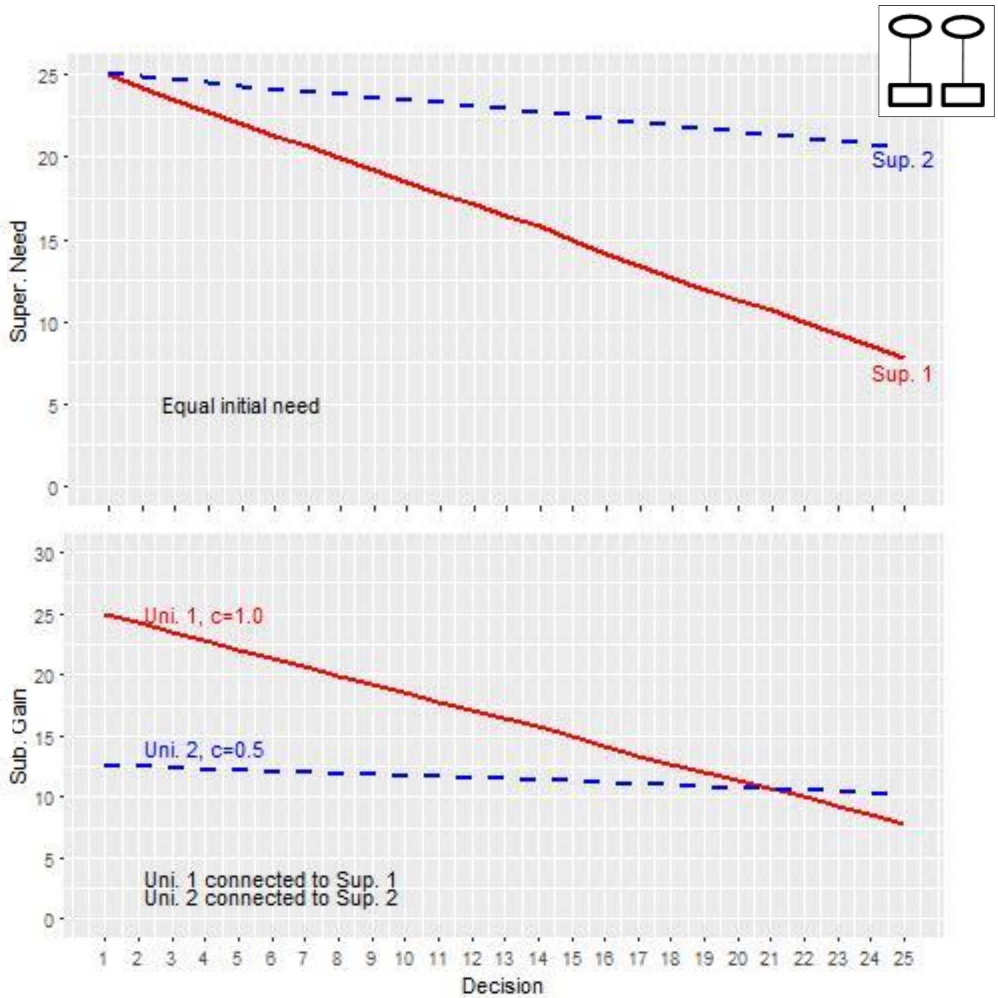

Figure 17. Instrumentality and gain, unifinal-unifinal, unequal instrumentality, two superordinate goals. *c*=instrumentality. Figure 17a represents the need of two superordinate goals across decisions. Figure 17b represents the gain of two unifinal subordinate goal, each connected to one of the two superordinate goals in Figure 17a, across decisions. Unifinal subordinate goal 1 has a higher instrumentality to superordinate goal 1 than unifinal subordinate goal 2 has to superordinate goal 2.

subordinate discrepancy and superordinate need, this discrepancy reduction is transferred to superordinate goal 1, reducing its need more quickly than that of superordinate goal 2 because of the higher instrumentality. An additional and unexpected pattern of relations was also observed within this goal system. More specifically, superordinate goal 1 eventually reached a low enough need that unifinal subordinate goal 2 – despite its lower instrumentality – achieved a higher gain than unifinal subordinate goal 1 (see decisions 21 through 25). This effect is explored and elaborated upon further in the predictive utility section.

A similar pattern as above was expected in the multifinal-multifinal configuration. It was predicted that a multifinal subordinate goal with a higher instrumentality set would have a higher gain than an alternative multifinal subordinate goal (*P9*). Figures 18a and 18b represent this configuration, where multifinal subordinate goal 1 has a higher instrumentality set ($c_1 = c_2 = 1.0$) than multifinal subordinate goal 2 ($c_1 = c_2 = 0.5$). Though each subordinate goal is connected to both superordinate goals, a greater amount of value is transferred down to multifinal subordinate goal 1 than multifinal subordinate goal 2, resulting in its higher gain.

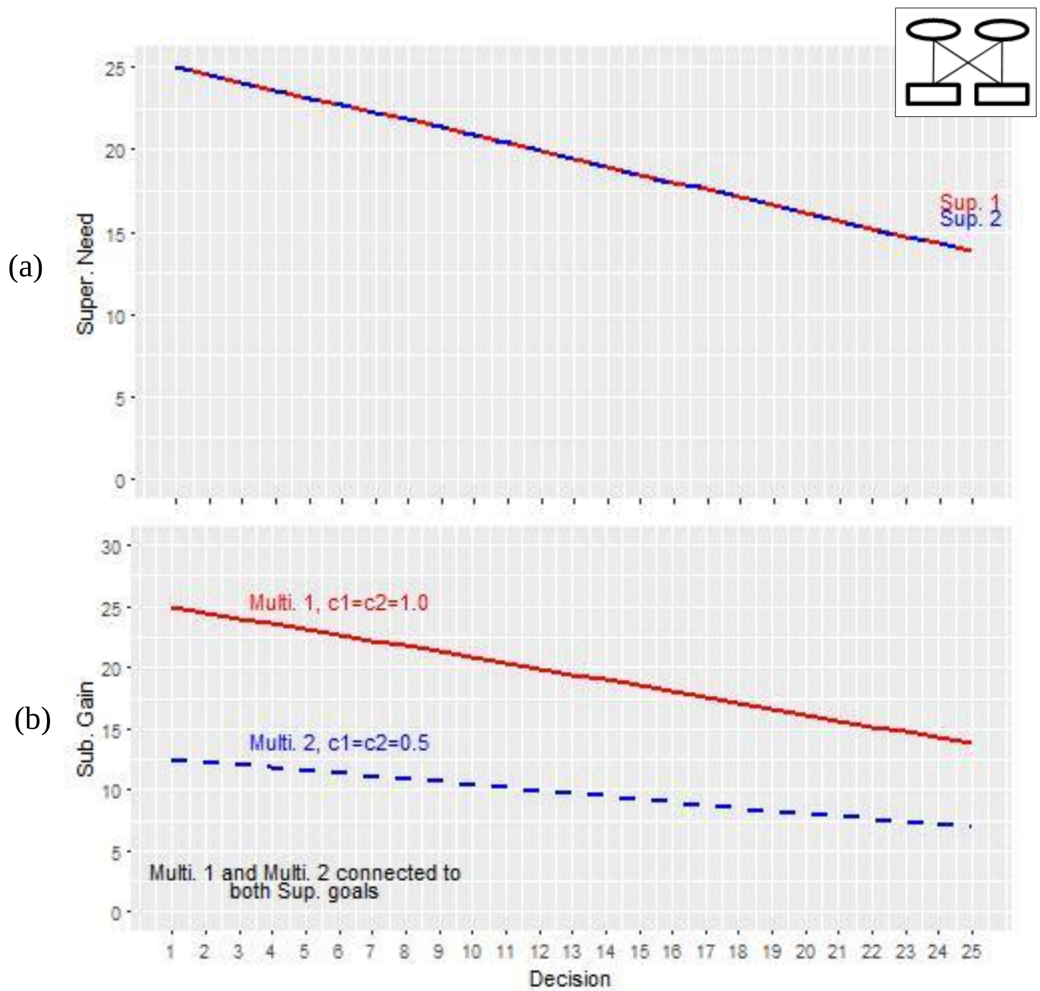

Figure 18. Instrumentality and gain, multifinal-multifinal, unequal instrumentality. c_h=instrumentality to superordinate goal *h*. Figure 18a represents the need of two superordinate goals across decisions. Figure 18b represents the gain of two multifinal subordinate goals connected to the superordinate goals in Figure 18a, across decisions. Multifinal subordinate goal 1 has a higher instrumentality set than multifinal subordinate goal 2.

In sum, these patterns of gain derivation described above support predictions 6 through 9, and demonstrate that the proposed relationship between instrumentality and subordinate gain is operationalized as intended in the HMGPM. When superordinate perceived importance is held constant, subordinate goals in unifinal-unifinal or multifinal-multifinal configurations have equal gain if they have equal instrumentality to the superordinate level. If their instrumentalities, or instrumentality sets, differ, the subordinate goal with the higher instrumentality to the superordinate level will have higher gain than the alternative subordinate goal. In other words, an individual perceives a lower-order goal to have higher value (i.e., gain) when it is more instrumental to higher-order goals than alternative lower-order goals.

Predictive Utility

The generative sufficiency results suggest the core concepts of the HMGPM and their relationships behave in ways consistent with their theorized underlying processes. Thus, the model's utility in explaining existing empirical findings and advancing new hypotheses for future research can be evaluated with greater confidence. The following results address predictions made concerning goal switching (Schmidt & Deshon, 2007; Vancouver et al., 2010), the value of multifinal goals in goal pursuit (Kopetz et al., 2011; Kruglanski et al., 2013), the pursuit of a goal under conditions of low expectancy, and dynamics of superordinate perceived importance across a goal network.

Goal Switching. Under conditions that simulate Schmidt and DeShon's (2007) college scheduling task, where two unifinal subordinate goals are equally as instrumental to the same single superordinate goal and progress on either subordinate goal is mutually exclusive, the current model predicts that goal switching will first be driven by discrepancy, then by expectancy as time approaches the deadline (*P10*).

Figures 19a through 19c represent a configuration where two unifinal subordinate goals are equally instrumental to a single superordinate goal.[1] As addressed above, two subordinate

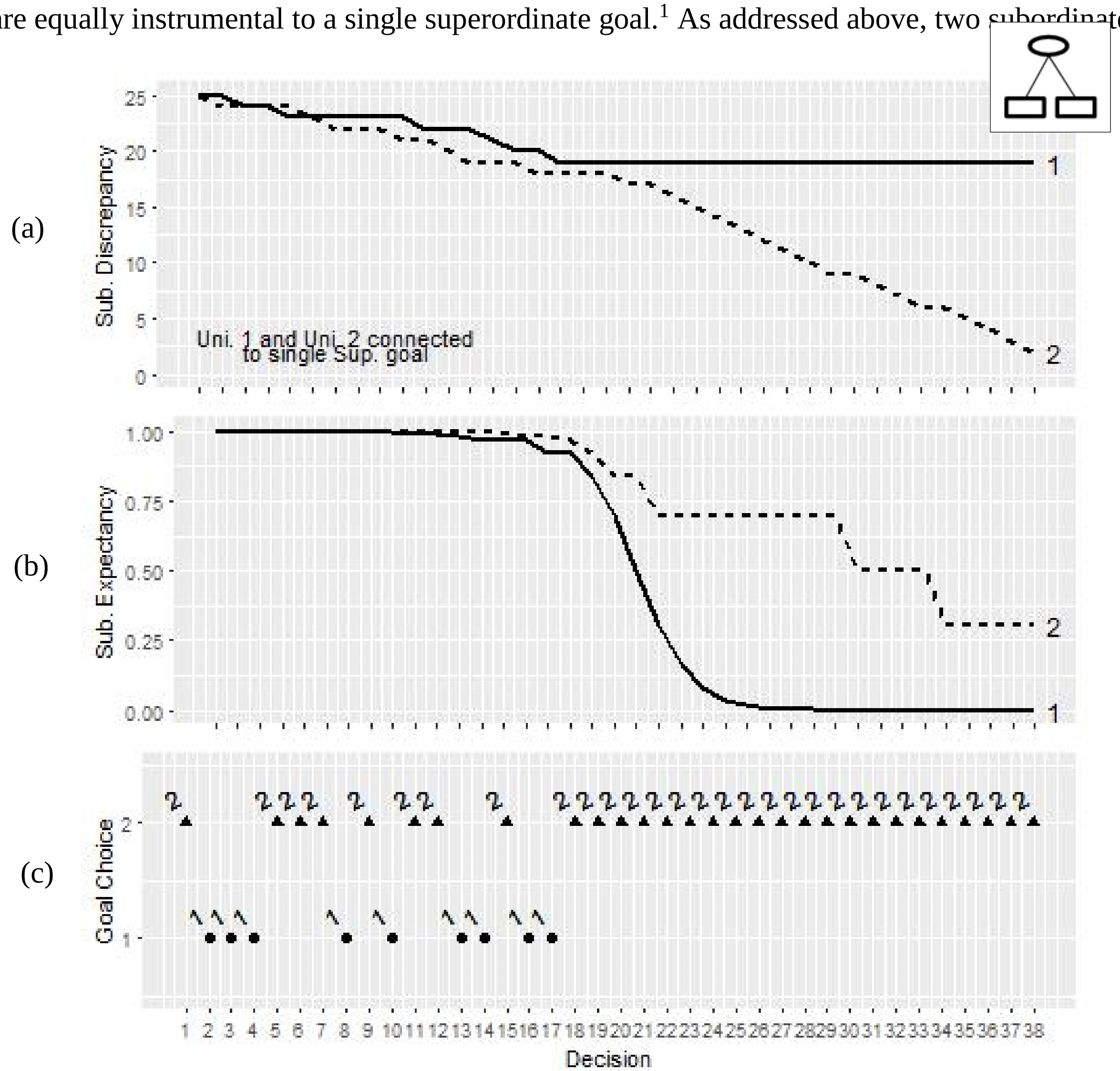

Figure 19. Goal switching, unifinal-unifinal. Figures 19a-c represent a unifinal-unifinal configuration where both unifinal subordinate goals are equally instrumental to a single superordinate goal. Their discrepancies and expectancies are represented across decisions (Figures 19a and 19b, respectively), and the goal chosen by the simulation at each decision is presented in Figure 19c.

[1] Because there is no initial difference between subordinate goals 1 and 2 under these conditions (i.e., their discrepancies and expectancies are equal, and they derive their gain from the same superordinate goal), the subordinate goal that is ultimately neglected is arbitrary – there is no reason to expect it to be subordinate goal 1 over subordinate goal 2, and vice versa. As a result, subordinate goal 1 was neglected in some simulations of this condition and subordinate goal 2 was neglected in others. If simulations were averaged at each decision, the observed pattern would be negated. Thus, Figures 19 and 20 demonstrate a single simulation within their respective conditions.

goals with equal instrumentalities to a single superordinate goal have equal gain, meaning goal choice should be driven by their discrepancies and expectancies. As expected, early in the simulation (decisions 1 through 18), the subordinate goals' expectancies are similar (Figure 19b) and goal choice favors the subordinate goal with the higher discrepancy (Figures 19a and 19c)[2]. As their expectancies diverge, goal choice begins to favor the subordinate goal with the higher expectancy (Figure 19c; subordinate goal 2, in this case), neglecting the alternative subordinate goal entirely.

In the hierarchical goal pursuit context, this pattern emerges because subordinate goal gains are equal. Because two multifinal subordinate goals with equal instrumentality sets derive equal gain from the superordinate level (as discussed in terms of generative sufficiency), this pattern was also expected in the multifinal-multifinal case (an extension of Schmidt and Deshon's, 2007, and Vancouver et al.'s, 2010, findings). Figures 20a through 20c represent this configuration. Initially (decisions 1 through 11), goal choice favors the multifinal subordinate goal with the higher discrepancy (Figure 20a and 20c) because their expectancies are similar (Figure 20b). As their expectancies diverge, goal choice favors the subordinate goal with higher expectancy (in this case, multifinal subordinate goal 1), and the alternative subordinate goal is neglected.

The above results address configurations where the finality of the subordinate goals is the same (i.e., unifinal-unifinal or multifinal-multifinal) and the perceived importance of the superordinate goals are equal, resulting in equal derived gain. However, the HMGPM also permits an extension of this framework to situations in which subordinate goals may have

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[2] The deadline in simulations of the goal switching effect in the unifinal-unifinal and multifinal-multifinal configurations was set at 76 "time units" instead of 50. This longer deadline was more consistent with the context of Schmidt and Deshon's (2007) study and allowed the pattern of an early preference for higher discrepancy to be demonstrated more clearly by preventing the subordinate goals' expectancies from quickly diverging.

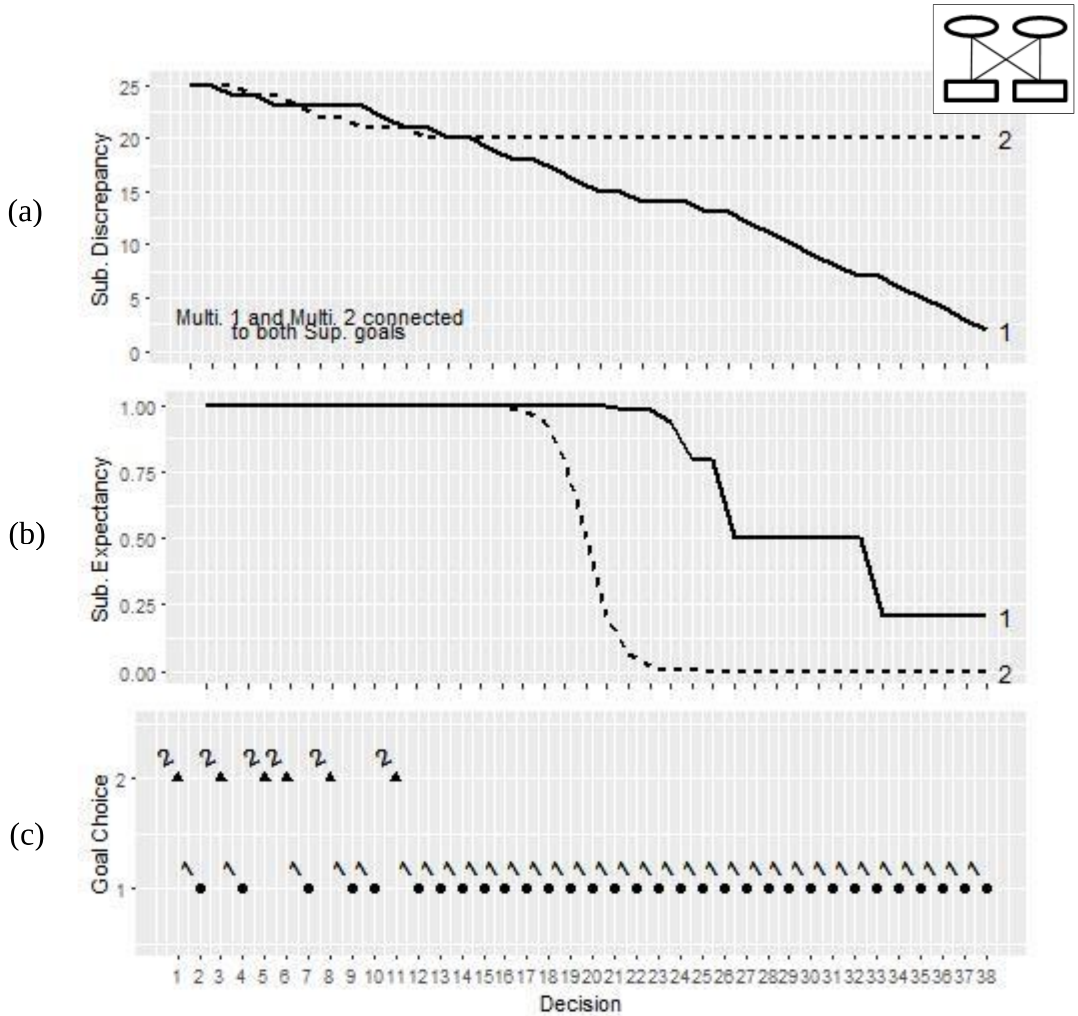


Figure 20. Goal switching, multifinal-multifinal. Figures 20a-c represent a multifinal-multifinal configuration where both multifinal subordinate goals are equally instrumental to two superordinate goals. Their discrepancies and expectancies are represented across decisions (Figures 20a and 20b, respectively), and the goal chosen by the simulation at each decision is presented in Figure 20c.

unequal instrumentalities with their superordinate goals as well as to unifinal-multifinal configurations, such as in Schmidt and DeShon's (2007) study where one scheduling task was also instrumental to a monetary incentive.

In these circumstances, subordinate goal choice is influenced by the value of the subordinate goals derived from the superordinate level. It was predicted that under conditions in which a multifinal goal and a unifinal goal have equal instrumentalities to a superordinate goal with higher perceived importance (i.e., need), the multifinal goal would have a higher gain because of the additional value it derives from the alternative superordinate goal to which the unifinal goal is not connected (*P11*).

Figures 21a and 21b represent this configuration. In this case, superordinate goal 1 has a higher initial need than superordinate goal 2 and is connected to both subordinate goals (Figure 21a). Contrary to the prediction, Figure 21b shows that the multifinal subordinate goal does not have a higher gain than the unifinal subordinate goal. When superordinate goal 1 has a higher need than superordinate goal 2, the unifinal subordinate goal has a higher derived gain than the multifinal subordinate goal. This unanticipated outcome can be explained by the scaling of instrumentalities when a subordinate goal is multifinal. While the “true” instrumentalities of the multifinal subordinate goal result in a higher derived gain (κ_M) than that of the unifinal subordinate goal (κ_U; e.g., $\kappa_U = 0.5(15) = 7.5$, $\kappa_M = 0.5(15 + 10) = 12.5$), the scaled instrumentalities do not ($c_{M1} = c_{M2} = 0.5(0.5) = 0.25$; $\kappa_M = 0.25(15 + 10) = 6.25$).

This observed pattern, where the unifinal subordinate goal is preferred over the multifinal subordinate goal because of its higher instrumentality to the superordinate goal with the higher need, is consistent with research on the dilution model of self-regulation (Zhang et al., 2007). An increase in the number of superordinate goals to which a subordinate goal is instrumental decreases its perceived effectiveness in satisfying each of those superordinate goals and therefore its likelihood of being chosen is diminished when only one of those superordinate goals is activated. In the context represent by Figures 21a and 21b, the higher initial need of superordinate goal 1 can be interpreted as a higher activation than that of superordinate goal 2. Because the multifinal subordinate goal is connected to both superordinate goals, it is perceived as less effective in satisfying superordinate goal 1. Thus, the unifinal subordinate goal is more valuable.

(a)

(b)

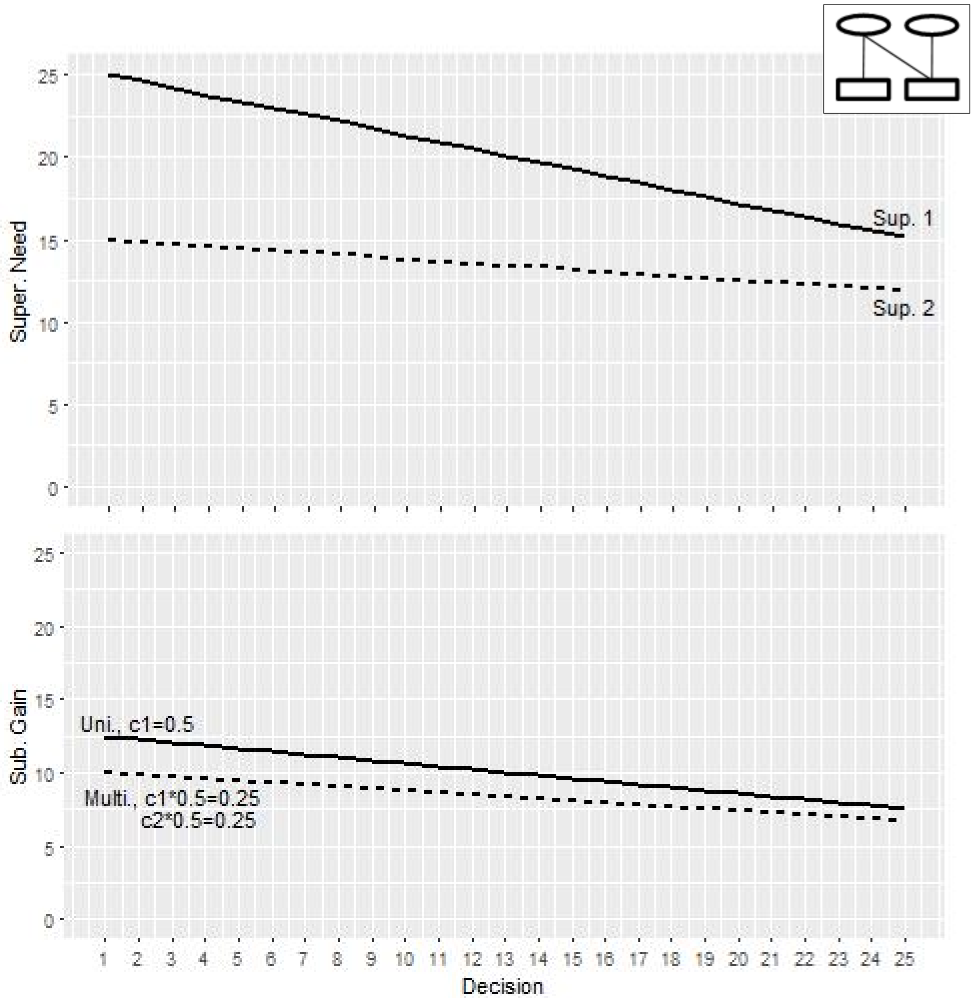


Figure 21. Goal switching, unifinal-multifinal. Figures 21a and 21b represent a unifinal-multifinal configuration where the unifinal and multifinal subordinate goals are both connected to the superordinate goal with higher initial need. Figure 21a represents the need of the superordinate goals across decisions. Figure 21b represents the gain of the subordinate goals across decisions.

In summary, the above results show that the HMGPM was capable of replicating Schmidt and DeShon's (2007) goal switching findings. In addition, the results of these predictive utility tests demonstrated the capability of the model to extend Schmidt and Deshon's (2007) findings into the multifinal-multifinal framework as well as advance new predictions about the pattern of gain in unifinal-multifinal goal systems that are consistent with previous research on the dilution model of self-regulation (Zhang et al., 2007). With regard to the final point, the HMGPM suggests that the connections between the multifinal subordinate goal and alternative superordinate goals decrease its perceived instrumentality to the focal superordinate goal, resulting in the unifinal subordinate goal being more valued more highly with respect to the focal superordinate goal.

The Value of Multifinality. The current model moves previous research on goals system (Kruglanski et al., 2002) into a dynamic context. In unifinal-multifinal goal configurations, the multifinal subordinate goal was predicted to be favored in goal choice when the unifinal subordinate goal was instrumental to the superordinate goal with lower perceived importance (*P12*; similar to Kopetz and colleagues', 2011, study of meal preferences). Figures 22a through 22c represent this configuration. Results from the simulations under this configuration show that the unifinal subordinate goal has lower gain than the multifinal subordinate goal (Figure 22a) because of the lower need of superordinate goal 2 (Figure 22b), from which it draws its only value. This results in favoring selection of the multifinal subordinate goal (Figure 22c).

The current model also predicts Kopetz et al.'s (2011) multifinal-multifinal scenario, where the multifinal subordinate goal with a higher instrumentality to the superordinate goal with the higher perceived importance is favored over the alternative multifinal subordinate goal (*P13*). Figures 23a through 23c represent this scenario. Superordinate goal 1 has a higher need than superordinate goal 2 (Figure 23a). Because multifinal subordinate goal 1 has a higher instrumentality to superordinate goal 1, it has a higher gain than multifinal subordinate goal 2 (Figure 23b) and is favored in goal choice (Figure 23c).

Lastly, the HMGPM predicts a similar pattern of goal choice in the unifinal-unifinal configuration, in which one unifinal subordinate goal is instrumental to a superordinate goal with higher perceived importance. Figures 24a through 24c represent this scenario. Superordinate goal 1 has a higher need than superordinate goal 2 (Figure 23a). Because of the instrumentality of

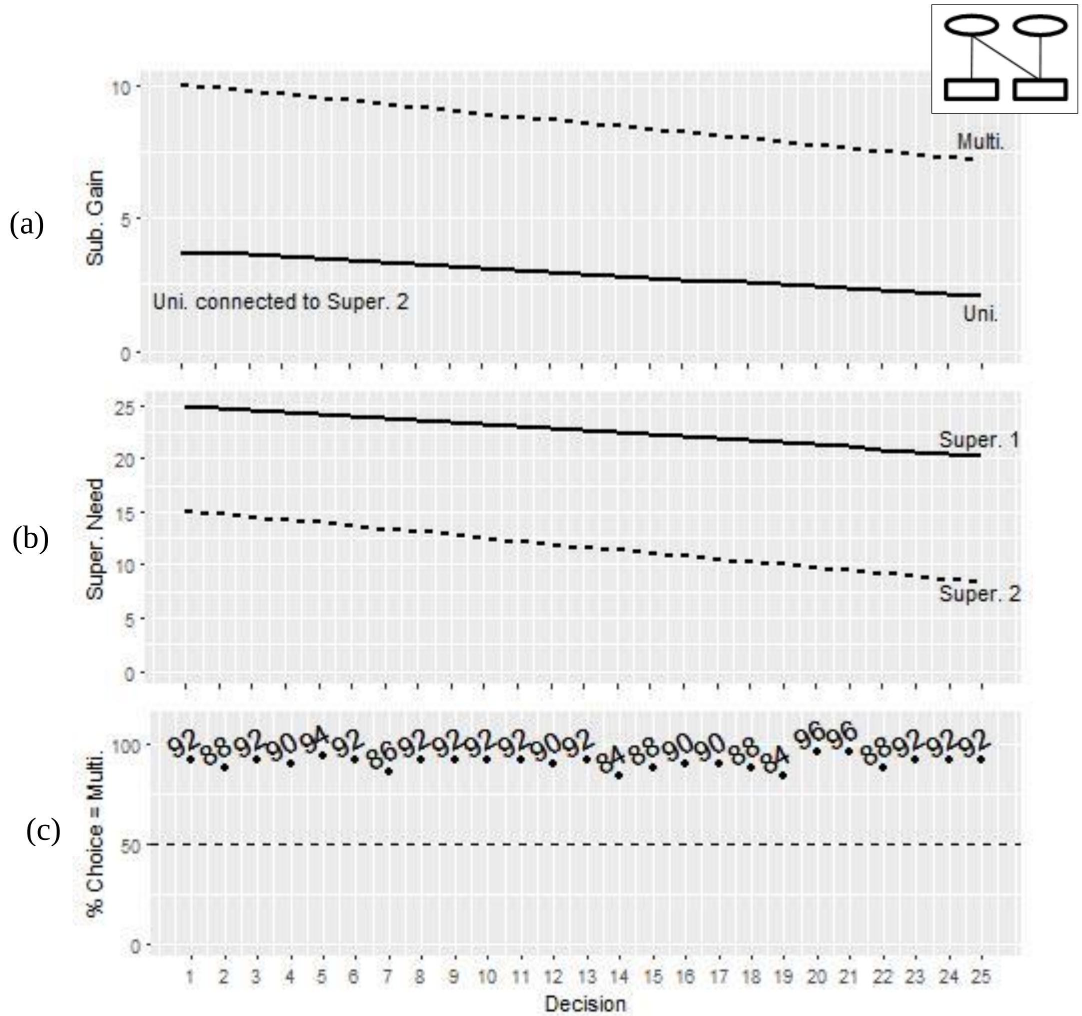


Figure 22. The value of multifinality, unifinal-multifinal. Figures 22a-c represent a unifinal-multifinal configuration where the unifinal subordinate goal is connected to the superordinate goal with a higher perceived importance. Figure 22a represents the gain of the subordinate goals across decisions. Figure 22b represents the need of the two superordinate goals across decisions. Figure 22c represents the percentage of simulations that chose the multifinal subordinate goal across decisions.

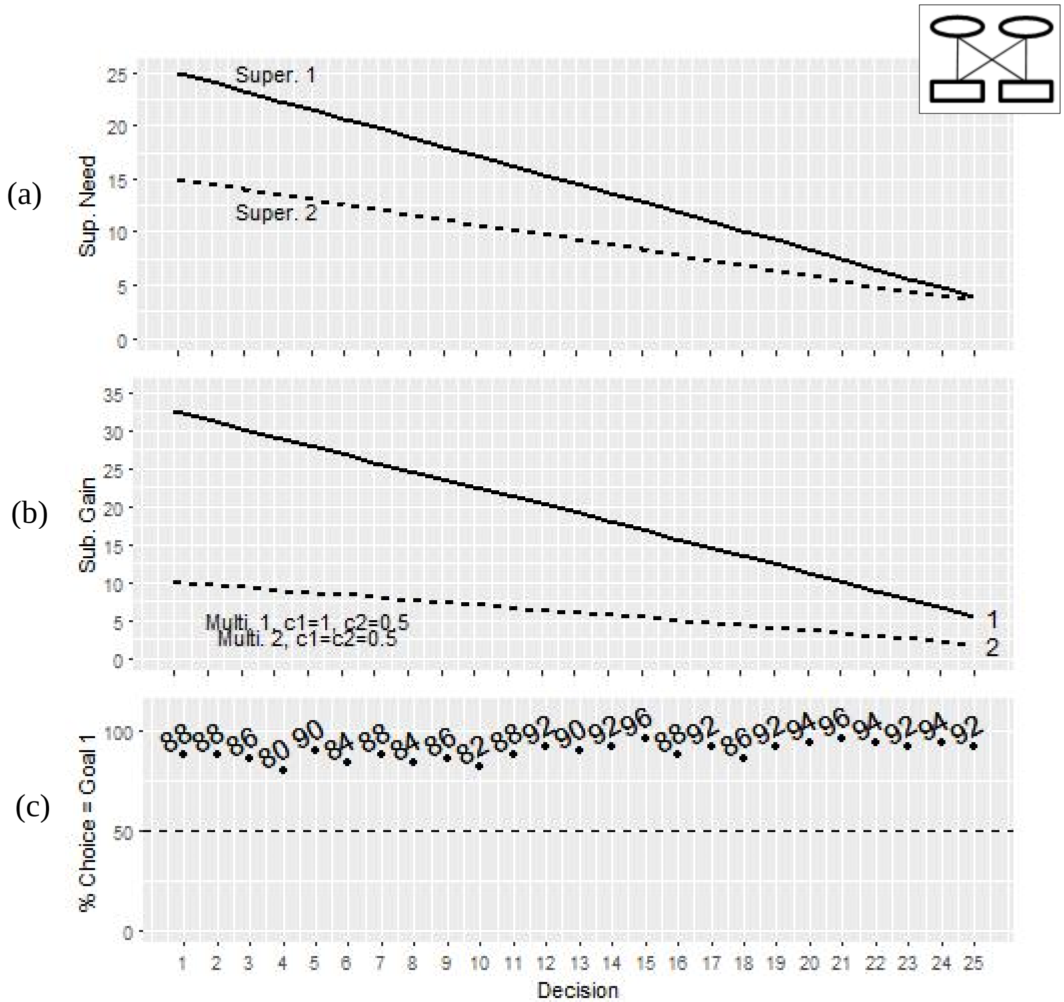


Figure 23.The value of multifinality, multifinal-multifinal. Figures 23a-c represent a multifinal-multifinal configuration where multifinal subordinate goal 1 is more instrumental to superordinate goal 1, which has a higher initial need than superordinate goal 2. Figure 23a represents the need of the two superordinate goals across decisions. Figure 23b represents the gain of the two multifinal subordinate goals across decisions. Figure 23c represents the percentage of simulations that chose multifinal subordinate goal 1 at each decision.

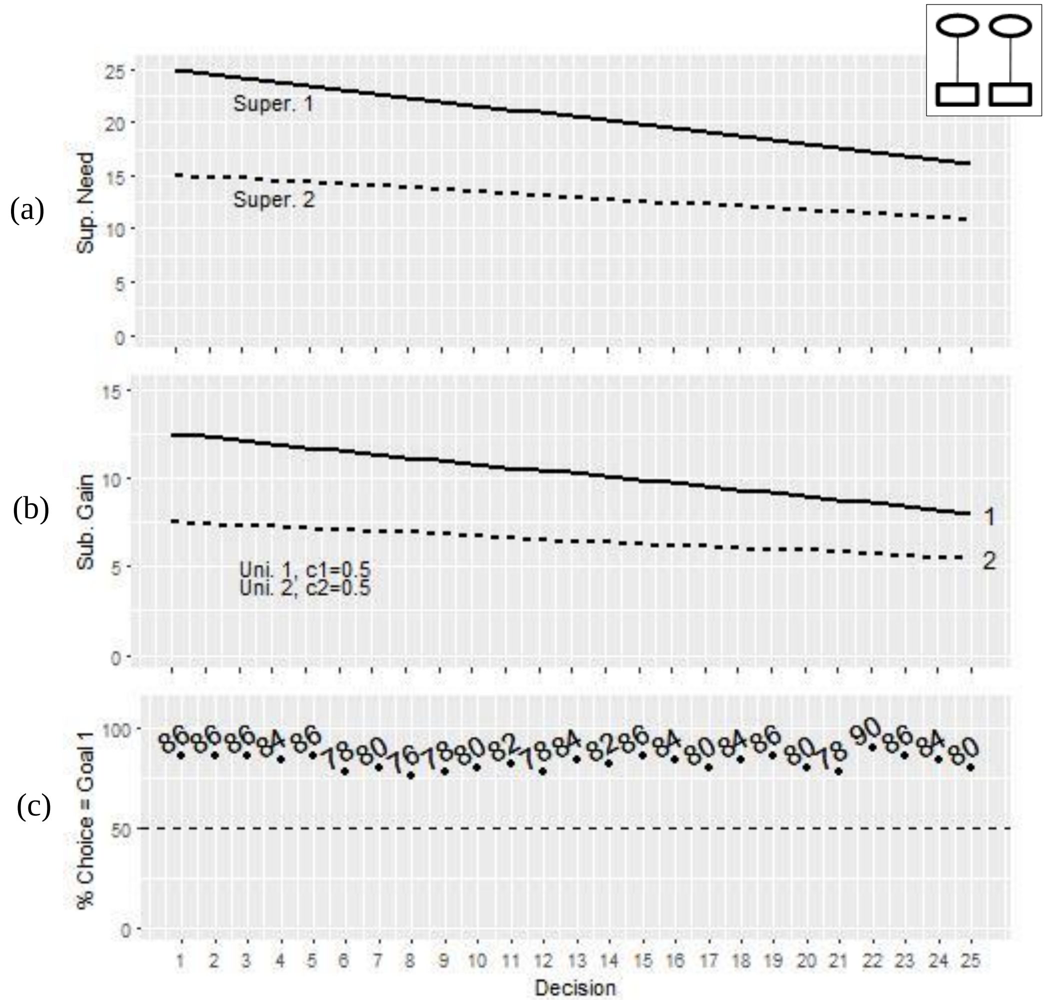


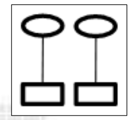
Figure 24. The value of multifinality, unifinal-unifinal. Figures 24a-c represent a unifinal-unifinal configuration where unifinal subordinate goal 1 is instrumental to superordinate goal 1, which as a higher need. Figure 24a represents the need of the superordinate goals across decisions. Figure 24b represents the gain of the two unifinal subordinate goals across decisions. Figure 24c represents the percentage of simulations that chose subordinate goal 1 at each decision point.

unifinal subordinate goal 1 to superordinate goal 1, unifinal subordinate goal 1 has a higher gain (Figure 23b) and is favored in goal choice (Figure 23c).

The above results demonstrate the utility of the HMGPM for replicating and advancing previous findings of Kopetz et al. (2011). The model predicts that multifinality is preferred to unifinality when the multifinal goal is more instrumental to the focal superordinate goal. Further, in unifinal-unifinal and multifinal-multifinal configurations, it predicts that a lower-order goal will be preferred to alternatives when it is most instrumental to the most important higher-order goal.

Unrealistic Optimism. Under conditions in which progress is not being made (i.e., discrepancy reduction is slow or inhibited), it was predicted that a subordinate goal with high instrumentality to a superordinate goal with a very high perceived importance would have a higher gain than an alternative subordinate goal. This higher gain was predicted to result in a focus on that subordinate goal, even when its expectancy of attainment was low, characterized as unrealistic optimism (*P14*). Figures 25a through 25e represent this configuration in a unifinal-unifinal context, where superordinate goal 1 has a much higher need than superordinate goal 2, and unifinal subordinate goal 1 has a higher instrumentality to superordinate goal 1 (c_{11} = 1) than unifinal subordinate goal 2 has to superordinate goal 2 (c_{22} = 0.5). The higher instrumentality between subordinate goal 1 and superordinate goal 1 and the extreme difference in need between the superordinate goals results in subordinate goal 1 deriving a much higher gain than subordinate goal 2 (Figure 25a). This high gain results in the valence of subordinate goal 1 being greater than that of subordinate goal 2 (Figure 25b). This higher valence overcomes low levels of expectancy (Figure 25c), resulting in a higher overall expected utility (EU) for subordinate goal 1 (Figure 25d) and a higher likelihood of it being chosen compared to subordinate goal 2 (Figure 25e).

These results suggest that if an individual values a goal high enough due to the superordinate goals from which it derives its value, a low likelihood of attaining it may not stop them from pursuing it. The HMGPM specifically predicts this pattern of goal choice under conditions where attaining the goal is difficult. Thus, unrealistic optimism in situations where high goal value undermines the reality of low expectancy represents a unique topic for future research identified by the model.



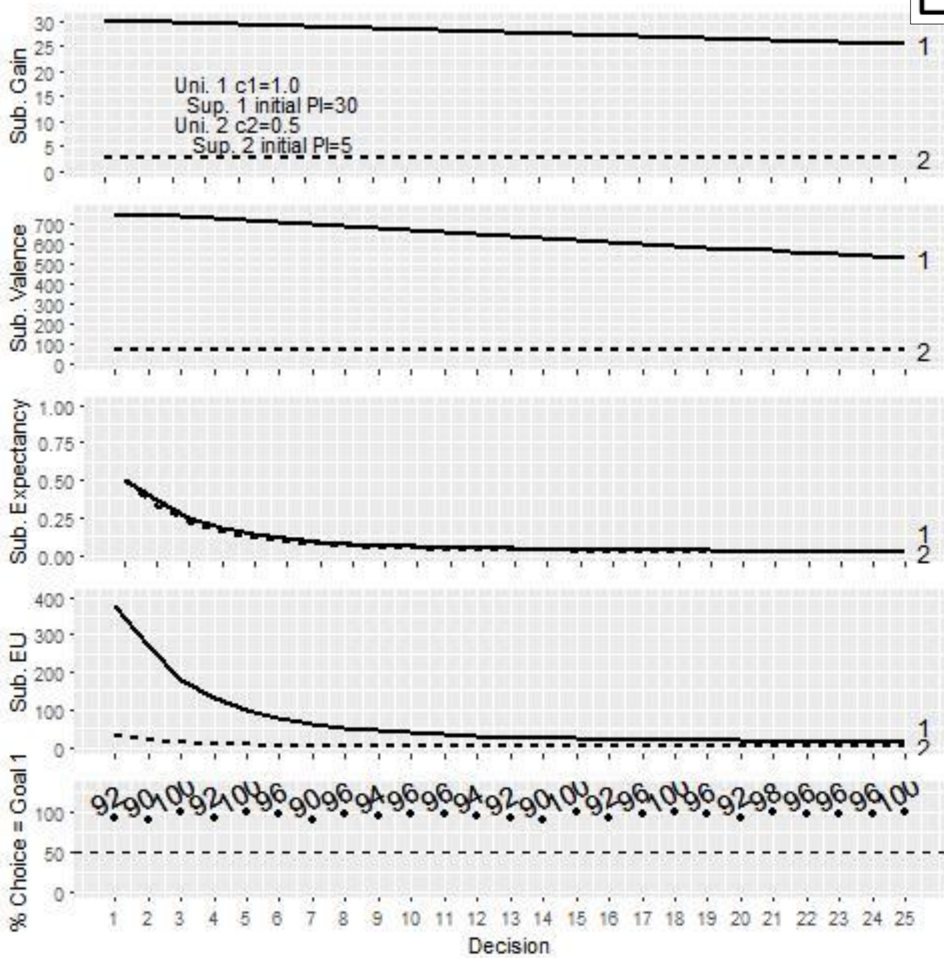


Figure 25. Unrealistic optimism. Figures 25a-e represent a unifinal-unifinal configuration, where unifinal subordinate goal 1 has a higher instrumentality to superordinate goal 1. Superordinate goal 1 has a much higher need than superordinate goal 2. Figure 25a represents the gain of the two subordinate goals across decisions. Figure 25b and 25c represent the valence and expectancies, respectively, of the two subordinate goals across decisions. Valence and expectancies are multiplied together to result in each subordinate goal's expected utility (EU), represented in Figure 25d across decisions. Figure 25e represents the percentage of simulations that chose to pursue subordinate goal 1 at each decision point.

Equalization of Superordinate Perceived Importance. In addition to predicting patterns at the subordinate level, the current model also allowed examination at the superordinate goal level over time. Specifically, the model predicts that initially high need of a superordinate goal would decrease as progress was made on the subordinate goal with the highest instrumentality to that superordinate goal, eventually reaching the lower level of need of alternative superordinate goals (*P15*).

Figures 26a through 26d represent this scenario in the unifinal-unifinal context. Subordinate goal 1 has a higher instrumentality to superordinate goal 1, which has a higher need than superordinate goal 2 (to which subordinate goal 2 is connected). The simulation initially favors subordinate goal 1 because of its higher gain (Figures 26a and 26b). Because this goal is favored, the discrepancy of subordinate goal 1 decreases at a faster rate than that of subordinate goal 2 (Figure 26c). This discrepancy reduction is transferred to superordinate goal 1 at a high rate because of the high instrumentality of subordinate 1, reducing its need (Figure 26d). This process decreases the need of superordinate goal 1 to not only match the need of superordinate goal 2, but to decrease below it.

Note that within the time frame of the simulation, the gain of subordinate goal 1 does not decrease below that of subordinate goal 2 (Figure 26a), despite the flip in superordinate goal needs. This is an effect of the higher instrumentality of subordinate goal 1. While superordinate goal 1 has a lower need than superordinate goal 2, the amount transferred to subordinate goal 1 is still higher than the amount transferred from superordinate goal 2 to subordinate goal 2 because its instrumentality is high. Theoretically, if the deadline were longer, subordinate goal 2 would eventually derive more gain from superordinate goal 2’s higher need and overcome subordinate goal 2’s gain.

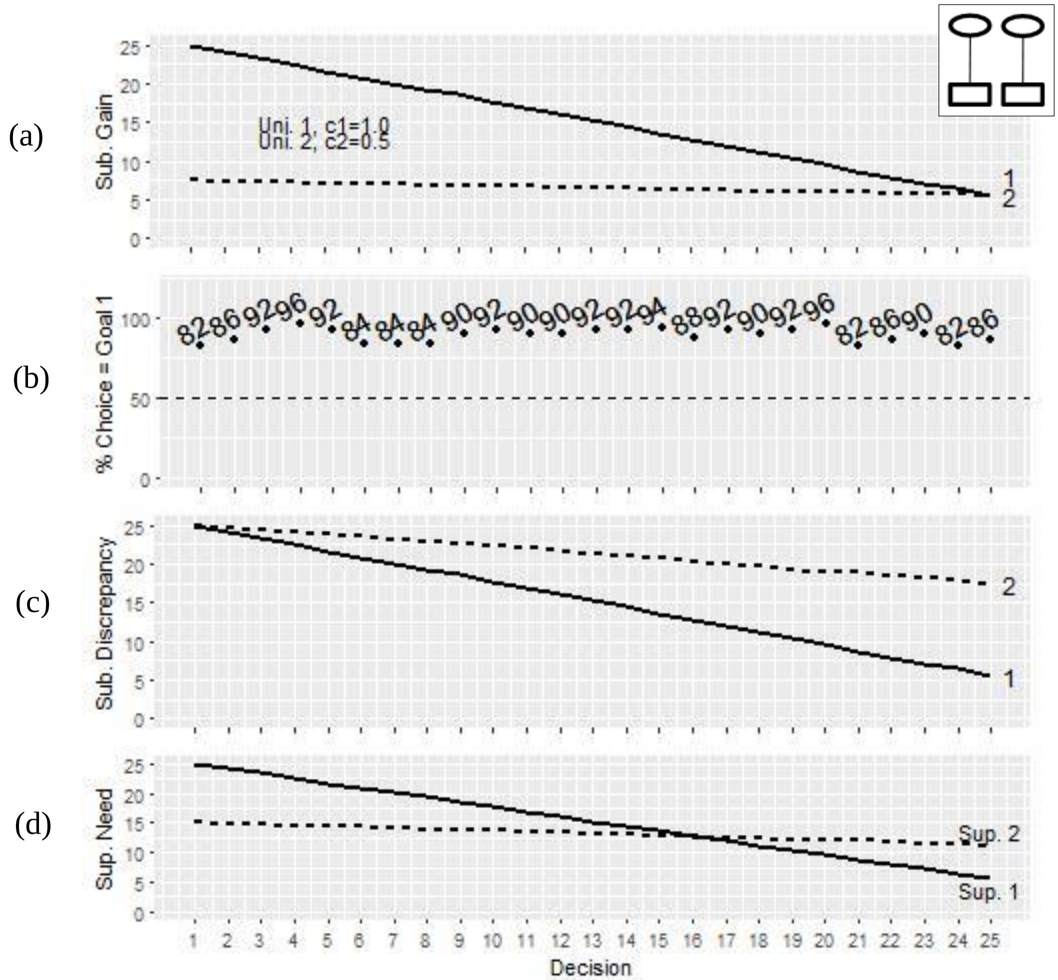


Figure 26. Equalization of superordinate perceived importance, unifinal-unifinal. Figures 26a-d represent a unifinal-unifinal configuration, where superordinate goal 1 has a higher need than superordinate goal 2, and subordinate goal 1 is more instrumental than subordinate goal 2 to superordinate goal 1. Figure 26a represents the gain of the two unifinal subordinate goals across decisions. Figure 26b represents the percentage of simulations that chose to pursue subordinate goal 1 at each decision point. Figure 26c represents the discrepancy of both subordinate goals across decisions. Figure 26d represents the need of both superordinate goal across decisions.

A similar pattern was observed in the multifinal-multifinal context (Figures 27a through 27d). Subordinate goal 1 has a higher gain than subordinate goal 2 because it has a higher instrumentality to superordinate goal 1, which has a higher need (Figure 27a). This higher gain results in subordinate goal 1 being favored in goal choice (Figure 27b). As the discrepancy of subordinate goal 1 is reduced (Figure 27c), the need of superordinate goal 1 is reduced, eventually equaling that of superordinate goal 2 (Figure 27d).

In the multifinal-multifinal configuration, the process is slower than in the unifinal-unifinal configuration (e.g., the need of superordinate goal 1 does not decrease below that of superordinate goal 2 within the time frame of the simulation). This is due to the scaling of instrumentalities in the multifinal-multifinal context. Thus, despite equal “true” instrumentalities to the unifinal-unifinal context, the multifinal instrumentalities are lower. These lower instrumentalities result in lower degrees of transfer of subordinate discrepancy reduction up to superordinate need.

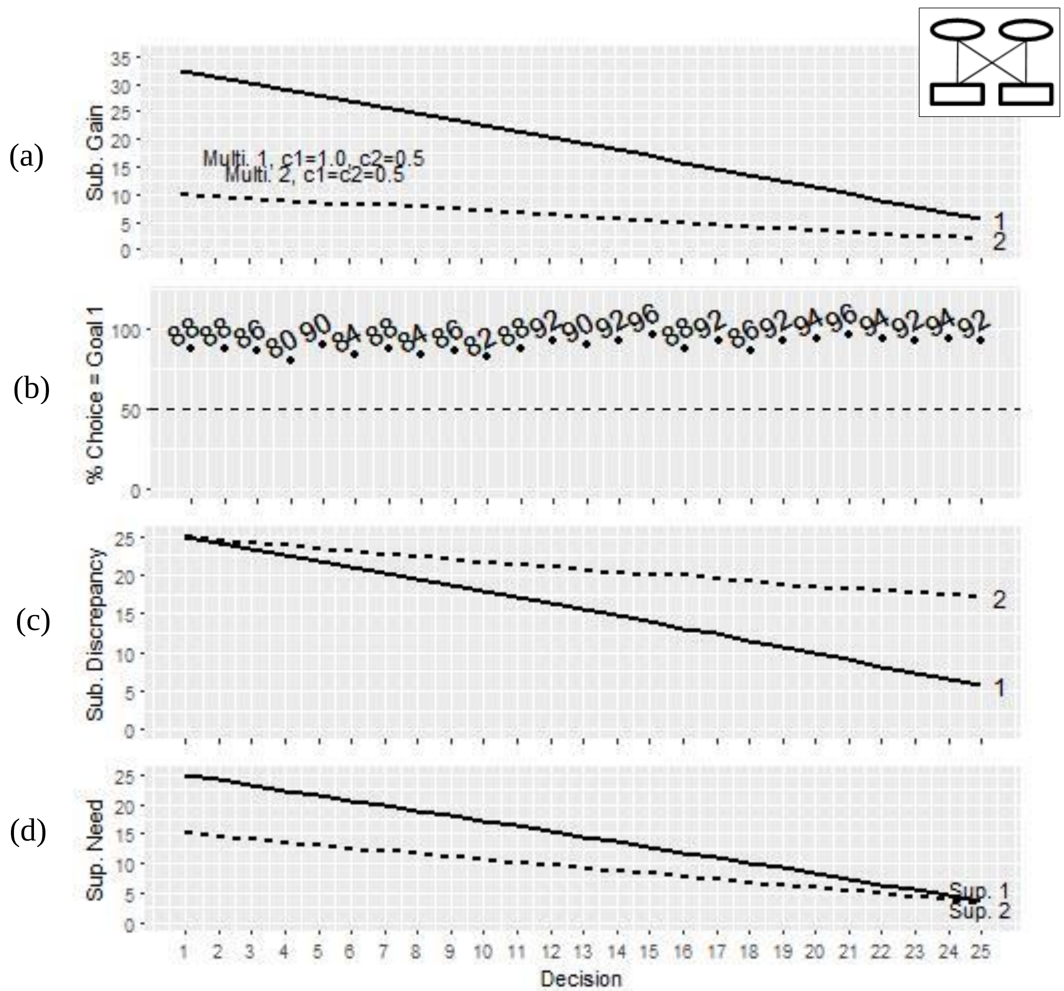


Figure 27. Equalization of perceived importance, multifinal-multifinal. Figures 27a-d represent a multifinal-multifinal configuration, where superordinate goal 1 has a higher need than superordinate goal 2, and subordinate goal 1 is more instrumental than subordinate goal 2 to superordinate goal 1. Figure 27a represents the gain of the two multifinal subordinate goals across decisions. Figure 27b represents the percentage of simulations that chose to pursue subordinate goal 1 at each decision point. Figure 27c represents the discrepancy of both subordinate goals across decisions. Figure 27d represents the need of both superordinate goal across decisions.

These patterns of superordinate goal perceived importance equalization put forth hypotheses for future research. Specifically, they suggest the relative importance (conceptualized as need) of higher-order goals in an individual's goal network changes as lower-order goals are successfully attained. These dynamics at the superordinate level trickle down, influencing the relative value (conceptualized as gain) of the lower-order goals in pursuit.

While not predicted initially, the delayed equalization of subordinate goals' gains compared to superordinate goals' needs is an interesting pattern produced by the HMGPM. Since it is a function of unequal instrumentalities, it suggests an individual may refrain from disengaging in a goal that they perceive to be highly effective at achieving a higher-order goal (i.e., a subordinate goal with high instrumentality), despite that higher-order goal being less important than others in the goal network.

The slower rate of change in the multifinal-multifinal configuration was also not predicted initially, but suggests an interesting side effect of multifinality. Because a multifinal subordinate goal is perceived to be less instrumental to any of its connected superordinate goals, an individual will perceive the attainment of higher-order goals to be slower when pursued via a multifinal subordinate goal than via a unifinal subordinate goal. This phenomenon and the delayed equalization of subordinate gains would be of interest in future research.

Discussion

The subjective evaluation of goal importance has been included in theories of goal choice and goal pursuit in some fashion from early motivational theories, such as Maslow's need hierarchy theory (1943) and Vroom's valence-instrumentality-expectancy theory (1964), to more recent computational models of self-regulation (Vancouver et al., 2010; Ballard et al., 2016). Despite its ubiquity, the derivation of subjective goal value has remained underspecified. By placing goal pursuit in a hierarchical framework, the current model and simulation results illuminate one process by which individuals evaluate goal value.

The HMGPM suggests that subordinate goals derive their value (i.e., gain) from higher levels in their goal hierarchy (i.e., superordinate goals) to the extent that they are instrumental to their attainment. The more instrumental a subordinate goal is to a superordinate goal, the more value it derives from that superordinate goal. This derived value and its relative magnitude to other goals' derived values in an individual's goal network ultimately influence how that individual chooses which of multiple goals to pursue.

The HMGPM successfully predicts patterns of goal evaluation and pursuit observed in the empirical literature. It suggests that in Schmidt and DeShon's (2007) study of multiple-goal pursuit, participants derived equivalent values for the two scheduling tasks because they both were equally as instrumental to the same higher-level goal (e.g., completing the study). This equivalence in value resulted in participants switching between the two tasks first based on their distance from completing the tasks (i.e., discrepancies), then their likelihoods of completing each task (i.e., expectancies). This pattern and extensions of it in alternative goal configurations were observed in the current simulations.

The HMGPM also produces patterns of goal evaluation similar to those observed in Kopetz and colleagues' (2011) study of meal preferences, in which participants preferred a multifinal means to getting lunch (a superordinate goal with a lower need) when they had other important goals to accomplish. The simulations presented here suggest this preference is driven by the greater derived value of the multifinal means resulting from its connection to two superordinate goals versus the lower derived value of the unifinal means resulting from its single connection the superordinate goal with a lower perceived need. Beyond simulating this empirically-observed result, the current model also predicts the dynamics of this unifinal-multifinal goal configuration. If the perceived needs of the two superordinate goals begin to reverse over time due to goal progress at the subordinate level, the unifinal subordinate goal may become more valuable than the multifinal subordinate goal because of the weakening of the multifinal goal's perceived instrumentalities to each of the superordinate goals. This suggests that while participants in Kopetz et al's (2011) study preferred a quick lunch because of its multifinality to their desire for food and their desire to accomplish other goals, their preference may switch as they accomplish these other goals. They may prefer a meal that is unifinal and therefore more instrumental to their desire for food, such as a full meal from the dining hall, rather than a quick multifinal meal from the campus convenience store. This pattern observed in the simulation of the HMGPM is supported by Zhang et al.'s (2007) study of the dilution model of self-regulation.

Theoretical Implications

The HMGPM has implications for the field of motivational sciences as seen through both the organizational psychological and social psychological lenses. Through the former, motivation has traditionally been viewed as a process driven by expectancy, or the likelihood of the individual attaining the goal, and the individual’s “distance” from the goal. The underlying reason an individual completes a task at work has generally been considered separately from expectancy and distance, two components derived directly from the task itself. While need-motive-value theories, such as Maslow’s (1943) need hierarchy or intrinsic motivation theories (e.g., Deci & Ryan, 1980), propose why an individual might pursue a certain task, they have rarely been integrated with theories focused on elements of the task, such as Vroom’s (1964) VIE theory or Carver and Scheier’s (1982) control theory. The HMGPM blends these two perspectives by placing goal pursuit in a hierarchical framework, thereby proposing a way by which individuals derive value from their goals (i.e., via higher-order goals) and how that value influences their decision-making process. Further, by drawing from goals systems theory (Kruglanski et al., 2002) – a general theory of goal choice – the HMGPM allows for both tangible rewards, such as monetary pay, and more abstract incentives, such as the drive for competence, to be considered within the space of an individual’s goal pursuit. Thus, the HMGPM advances the field’s theoretical tools in the examination of self-regulation at work for both monetary and value- or -identity-driven incentives by emphasizing the multi-level dynamics of an individual’s goal pursuit.

In addition to its advances in organizational psychology, the development of the HMGPM also contributes to the social psychological perspective of motivation by extending goals systems theory (Kruglanski et al., 2002) from single-decision scenarios to those that involve multiple decisions. Research on goals systems theory has generally focused on choices between alternative goals that are not typically achieved incrementally (e.g., a choice between two types of food to satisfy a desire for health or for tastiness, versus a choice between incremental goals to exercise four times per week or read four research articles per week).

Certain predictions explored using the HMGPM in the current project were based on studies in the goals systems theory framework that used non-incremental goals, such as Kopetz et al.'s (2011) easy-to-get (i.e., speedier) versus difficult-to-get meal options. The HMGPM not only replicates findings in single-decision contexts, but also illuminates patterns of decision making between pairs of incremental goals, unifinal or multifinal. These simulation results provide a foundation for exploring these patterns through Kruglanski and colleagues' (2002) goals systems theory perspective in future empirical studies.

Limitations

While the HMGPM is proposed to apply to a number of goal pursuit scenarios with a diversity of characteristics and includes a wide array of parameters that capture these characteristics, it was not feasible to explore each to its fullest extent within the current project. Predictions related to unrealistic optimism, as it was referred to here, would particularly benefit from further development and exploration. While the results suggest extreme levels of subordinate gain may override effects of low expectancy, certain constraints within the current simulation may be lifted to reveal a different pattern of goal choice. Specifically, the current simulations forced the choice to pursue one of the subordinate goals. In other words, disengaging from both subordinate goals entirely was not an option. While the expectancy of attaining either subordinate goal approached zero in the current simulation, the extreme gain of one subordinate goal kept its expected utility slightly higher than that of the alternative, resulting in it being favored when goal choice was required. In certain scenarios, the option to disengage from both subordinate goals, independent of their gains, may be more realistic.

With respect to the scope of the HMGPM, the model is currently limited to goal choice and pursuit scenarios in which the concept of a deadline is relevant. This encompasses many instances of self-regulation in the workplace, in which employees are expected to finish a project by a certain date or complete a certain number of tasks per a given time period. Indeed, the HMGPM is able to replicate and extend empirically-observed patterns of multiple-goal pursuit with a deadline, such as Schmidt and Deshon's (2007) scheduling task. However, an individual's motivation is not limited to situations in which they need to complete a certain number of tasks or behaviors within a certain amount of time. This is especially the case in instances of motivation that may be of interest to those whose perspective is more aligned with goals systems theory (Kruglanski et al., 2002), such as the choice between engaging in activism on behalf of one cause or an alternative, versus work-focused theories. Because the conceptualization of expectancy in the HMGPM requires a deadline to calculate two of its components, time remaining and time required, the model as it currently stands may not capture multiple-goal pursuit in these contexts. A conceptualization of expectancy that relies less on discrete interpretations of time may broaden the type of goal pursuit the HMGPM is able to simulate. Further, while the current project included the individual difference parameter of sensitivity to a deadline, a less deadline-focused conceptualization of expectancy may better allow the consideration of other individual difference variables that influence one's perception of goal pursuit, their own ability, and time.

Future Directions

The current project puts forth new hypotheses for future research and sets the stage for further development of the HMGPM. With respect to the former, the patterns of superordinate need and subordinate gain equalization examined in the predictive utility portion of this project are of particular interest. The simulated results suggest that in a goal system where one subordinate goal is more instrumental to a superordinate goal with higher perceived importance, the superordinate goal's perceived importance will eventually decrease to that of other superordinate goals in the system. While superordinate perceived importance and subordinate gain are closely related components in the model, the equalization of the former does not directly translate to the equalization of the latter. Subordinate gain equalization tends to be delayed. This delay may imply an "ease" effect, whereby a higher perceived effectiveness (i.e., instrumentality) increases a lower-order goal's appeal because it more directly translates to the attainment of a higher-order goal, despite that higher-order goal being less important than others. Alternatively, it may imply a preference for efficacy, where the relative importance of higher-order goals is less influential in goal pursuit than an individual's perceived ability of attaining them. Though this phenomenon has interesting consequences for an individual attempting to self-regulate on multiple simultaneous tasks, it has not been empirically tested. This pattern would be an interesting focus of future replications and wider research streams.

Beyond exploring and replicating results of the current study in future research, further theoretical development and testing of the HMGPM may be beneficial in understanding the dynamics of goal pursuit in different contexts than examined here. As mentioned above, this model development may focus on the possibility of goal disengagement or new conceptualizations of expectancy. Exploration of the second proposed component of superordinate perceived importance – salience – is also a promising avenue for future research. In the HMGPM, superordinate perceived importance is theorized to be determined by 1) an individual's baseline need for the superordinate goal, and 2) dynamic increases in the importance of the superordinate goal influenced by an individual's environment or current state. This latter element is proposed to represent salience. Because of the additive nature of these two components, superordinate salience is expected to influence the derivation of subordinate gain in a similar way to superordinate need. However, the environmental influence that this component reflects could allow the HMGPM to explore the social dynamics of multiple-goal pursuit. For example, an individual's group identity may influence the importance of certain goals in their network. Group influence could be represented as a change in superordinate salience, which, depending on the goal context, may influence which subordinate goal the individual decides to pursue. Thus, elaborating upon the salience component would expand the scope of the HMGPM beyond the individual level and into group-level social contexts.

Conclusion

The current project and derivation of the HMGPM proposed a means by which goal value is derived. By situating self-regulatory models of goal choice in a hierarchical context, it provided an explanation for empirically-observed patterns of multiple-goal pursuit and highlighted potential areas of future research on the topic of goal pursuit. While the exploration of other core components of the model is of interest (e.g., salience), the HMGPM currently stands as a useful theoretical tool in the field of motivation psychology.

Appendix A

HMGPM Computational Model 'R' Code

```
hmgpm<-function(cond, ind, attn, multi1, multi2, superNum, need1, need2, inst11, inst21,
inst12, inst22, deadline) {

  #1. Set time (t.c), decision (d.c), decision matrix row (d.row.c), and sample (s.c) counters to 0
  t.c<-0
  d.c<-0
  s.c<-0
  d.row.c<-0

  #2. Initialize input variables, functions, and t.c=0 calculations
  ##a. Input variables
  ###i. Time sensitivity, gamma, of decision maker
  sens.inp<-round(abs(rnorm(1,.33,.25)),2)

  ###ii. Expected lag, alpha, for each subordinate goal
  lag1.inp<-2
  lag2.inp<-lag1.inp

  ###iii. Preference threshold, theta, for each subordinate goal
  thresh1.inp<-round(abs(rnorm(1, .3, .5)), 3)
  thresh2.inp<-thresh1.inp

  ###iv. Valence intercept, b, for approach v. avoidance goals - not used in current version of
model
  #b.appr.inp<-0
  #b.avoid.inp<-5 #Used by Ballard et al., 2016; ensured that the overall level of valence would
be approximately equal for approach and avoidance goals

  ###v. Finality for each subordinate goal
  multi1.inp<-multi1
  multi2.inp<-multi2

  ###vi. Number of superordinate goals
  superNum.inp<-superNum

  ###vii. Reference value, g, for each subordinate goal
  g1.inp<-25
  g2.inp<-g1.inp

  ###viii. Deadline
  end.inp<-deadline
```

```
###ix. Initial need, n, and salience, s, for each superordinate goal
n1.inp<-need1
n2.inp<-need2
s1.inp<-0
s2.inp<-0

###viii. Instrumentality, c, between each sub- and sup- goal (note: c12.inp=instrumentality
between sub- goal 1 and sup- goal 2)
c11.inp<-inst11
c12.inp<-inst12

c21.inp<-inst21
c22.inp<-inst22

###ix. Approach/avoidance for each sub-goal (1=approach)
appr1.inp<-1
appr2.inp<-1

###x. Consequence attention weights (i.e., likelihoods)
typical.cons.inp<-c(.2, .1, .65, .05, .2, .1, .05, .65)
me.cons.inp<-c(0, .2, .8, 0, 0, .2, 0, .8)
lp.cons.inp<-c(0, .8, .2, 0, 0, .8, 0, .2)

###xi. Quality of each consequence
####Success=move one closer to goal, fail=stay at current state

#Quality of "success"
qS.inp<-1

#Quality of "failure"
qF.inp<-0

##b. Functions

###i. Valence
valence.f<-function(gain, currState, reference, appr) {
  if(appr==1){
    valence<-max((gain*(reference-currState)), 0)
  } else {
    valence<-max(((gain*currState)+1), 0)
  }
  return(valence)
}

###ii. Expectancy
expectancy.f<-function(lag, sens, currState, reference, currTime, deadline, appr){
```

```
  TA<-(deadline-currTime)
  if(appr==1) {
   TR<-(lag*(reference-currState))
  } else {
   TR<-lag
  }
  expectancy<-(1/(1+exp(((-1)*sens)*(TA-TR))))
  return(expectancy)
 }

 ###iii. Need
 needChange.f<-function(currState1, inst1, appr1, currState2, inst2, appr2) {
  needChange1<-(currState1*inst1)
  needChange2<-(currState2*inst2)
  if(appr1==1){
   needChange1<-((-1)*needChange1)
  }
  if(appr2==1){
   needChange2<-((-1)*needChange2)
  }
  needChangeT<-(needChange1+needChange2)
  return(needChangeT)
 }

 ##c. Matrices/arrays
 ###i. Consequence matrix (sub- goal x variable)
 conseq.mat<-matrix(data=0, nrow=2, ncol=8)
 colnames(conseq.mat)<-c("BothSuccessQ.s", "BothFailQ.s", "Sub1SuccessQ.s",
"Sub2SuccessQ.s", "BothSuccessW.s", "BothFailW.s", "Sub1SuccessW.s", "Sub2SuccessW.s")
 rownames(conseq.mat)<-c(1:nrow(conseq.mat))

 conseq.mat[c(1:2), c("BothSuccessQ.s", "BothFailQ.s", "Sub1SuccessQ.s",
"Sub2SuccessQ.s")]<-rbind(c(qS.inp, qF.inp, qS.inp, qF.inp), c(qS.inp, qF.inp, qF.inp, qS.inp))

 if(attn==1) {

  conseq.mat[c(1:2), c("BothSuccessW.s", "BothFailW.s", "Sub1SuccessW.s",
"Sub2SuccessW.s")]<-typical.cons.inp

 } else if(attn==2) {

  conseq.mat[c(1:2), c("BothSuccessW.s", "BothFailW.s", "Sub1SuccessW.s",
"Sub2SuccessW.s")]<-me.cons.inp

 } else if(attn==3) {
```

```
    conseq.mat[c(1:2), c("BothSuccessW.s", "BothFailW.s", "Sub1SuccessW.s",
"Sub2SuccessW.s")]<-lp.cons.inp

  }

  ###ii. Decision matrix (sample x variable); includes momentary attrativeness of each goal and
preference for each decision
  decision.mat<-matrix(data=0, nrow=10000, ncol=8)
  colnames(decision.mat)<-c("Cond", "Individual", "Decision", "Sample", "Time", "MA1.v",
"MA2.v", "Pref.v")
  rownames(decision.mat)<-c(1:nrow(decision.mat))

  ###iii. Subordinate array (decision x variable x sub- goal)
  sub.arr<-array(data=0, dim=c(100,32,2), dimnames=list(c(1:100), c("Cond", "Individual",
"Decision", "Time", "Appr.s", "Multi.s", "Lag.s", "Thresh.s", "Ref.s", "Inst1.s", "Inst2.s",
"CurrState.v", "Discrep.v","PercRemain.v", "ChanceAttnRemain.v", "AttnRemain.v", "Gain.v",
"Valence.v", "TR.v", "TA.v", "Expect.v", "EU.v", "MVConseq1.v", "MVConseq2.v",
"MVConseq3.v", "MVConseq4.v", "MVConseq1Sc.v", "MVConseq2Sc.v", "MVConseq3Sc.v",
"MVConseq4Sc.v", "FocalGoal.v", "ConseqReal.v"), c("SubGoal1", "SubGoal2")))

  ###iv. Superordinate array (decision x variable x sup- goal)
  sup.arr<-array(data=0, dim=c(100,8,2), dimnames=list(c(1:100), c("Cond", "Individual",
"Decision", "Time", "Need.v", "DeltaS1.v", "DeltaS2.v", "Salience.v"), c("SupGoal1",
"SupGoal2")))

  ###v. Fill in static and initial values
  sub.arr[, c("Cond", "Individual", "Appr.s", "Multi.s", "Lag.s", "Thresh.s", "Ref.s", "Inst1.s",
"Inst2.s"), 1]<-rep(c(cond, ind, appr1.inp, multi1.inp, lag1.inp, thresh1.inp, g1.inp,
c11.inp/(multi1.inp+1), c12.inp/(multi1.inp+1)), each=nrow(sub.arr))
  sub.arr[, c("Cond", "Individual", "Appr.s", "Multi.s", "Lag.s", "Thresh.s", "Ref.s", "Inst1.s",
"Inst2.s"), 2]<-rep(c(cond, ind, appr2.inp, multi2.inp, lag2.inp, thresh2.inp, g2.inp,
c21.inp/(multi2.inp+1), c22.inp/(multi2.inp+1)), each=nrow(sub.arr))

  sup.arr[, c("Cond", "Individual", "Need.v", "Salience.v"), 1]<-rep(c(cond, ind, n1.inp, s1.inp),
each=nrow(sup.arr))
  sup.arr[, c("Cond", "Individual", "Need.v", "Salience.v"), 2]<-rep(c(cond, ind, n2.inp, s2.inp),
each=nrow(sup.arr))

  decision.mat[,"Cond"]<-cond
  decision.mat[,"Individual"]<-ind

  while(t.c < end.inp){
    ##c. Update values
    ###i. Increment decision, update current time, time available
    d.c<-d.c+1
```

```
  sub.arr[d.c, c("Decision", "Time", "TA.v"), c(1:2)]<-rep(c(d.c, t.c, end.inp-t.c),2)

  sup.arr[d.c, c("Decision", "Time"), c(1:2)]<-rep(c(d.c, t.c),2)

  ###ii. Update current state based on consequence realized
  if(t.c > 0) {
    sub.arr[(d.c-1), "ConseqReal.v", c(1:2)]<-sample(c(1:4), size=1,
prob=conseq.mat[sub.arr[(d.c-1), "FocalGoal.v",1], c("BothSuccessW.s", "BothFailW.s",
"Sub1SuccessW.s", "Sub2SuccessW.s")])

    sub.arr[d.c,"CurrState.v",c(1,2)]<-c(sub.arr[(d.c-1),"CurrState.v", 1] + conseq.mat[1,
sub.arr[(d.c-1), "ConseqReal.v", 1]],
                    sub.arr[(d.c-1),"CurrState.v", 2] + conseq.mat[2, sub.arr[(d.c-1),
"ConseqReal.v", 1]])
  }

  ###iii. Discrepancy, d, for each subordinate goal, k
  sub.arr[d.c, "Discrep.v", c(1:2)]<-c(max(g1.inp-sub.arr[d.c,"CurrState.v",1], 0),
                    max(g2.inp-sub.arr[d.c,"CurrState.v",2], 0))

  ###iv. Need, n
  ####a.     For each superordinate goal, h, reduce need, n, by discrepancy reduced scaled by
instrumentality, c, for each goal.
  sup.arr[d.c,"Need.v",c(1:2)]<-c(max(sup.arr[d.c,"Need.v",1]+(needChange.f(sub.arr[d.c,
"CurrState.v",1], sub.arr[d.c,"Inst1.s",1], sub.arr[d.c, "Appr.s",1],sub.arr[d.c, "CurrState.v",2],
sub.arr[d.c,"Inst1.s",2], sub.arr[d.c, "Appr.s",2])), 0),
                  max(sup.arr[d.c,"Need.v",2]+(needChange.f(sub.arr[d.c, "CurrState.v",1],
sub.arr[d.c,"Inst2.s",1], sub.arr[d.c, "Appr.s",1],sub.arr[d.c, "CurrState.v",2],
sub.arr[d.c,"Inst2.s",2], sub.arr[d.c, "Appr.s",2])), 0))

  ###v.     Salience - not used in current version of model

  ###vi. Valence, v, for each subordinate goal, k
  ####1. Gain
  sub.arr[d.c, "Gain.v", c(1:2)]<-
c((sub.arr[d.c,"Inst1.s",1]*(sup.arr[d.c,"Need.v",1]+sup.arr[d.c,"Salience.v",1])+sub.arr[d.c,"Inst
2.s",1]*(sup.arr[d.c,"Need.v",2]+sup.arr[d.c,"Salience.v",2])),

(sub.arr[d.c,"Inst1.s",2]*(sup.arr[d.c,"Need.v",1]+sup.arr[d.c,"Salience.v",1])+sub.arr[d.c,"Inst2.
s",2]*(sup.arr[d.c,"Need.v",2]+sup.arr[d.c,"Salience.v",2])))

  ####2. Valence
  sub.arr[d.c,"Valence.v",c(1:2)]<-c(valence.f(sub.arr[d.c,"Gain.v",1], sub.arr[d.c,
"CurrState.v",1], sub.arr[d.c, "Ref.s",1], sub.arr[d.c, "Appr.s", 1]),
                   valence.f(sub.arr[d.c,"Gain.v",2], sub.arr[d.c, "CurrState.v",2],
sub.arr[d.c, "Ref.s",2], sub.arr[d.c, "Appr.s", 2]))
```

```
###vii. Expectancy, e, for each subordinate goal, k
sub.arr[d.c, "Expect.v", c(1:2)]<-c(expectancy.f(sub.arr[d.c,"Lag.s",1], sens.inp, sub.arr[d.c,
"CurrState.v",1], sub.arr[d.c, "Ref.s",1], t.c, end.inp, sub.arr[d.c, "Appr.s", 1]),
                          expectancy.f(sub.arr[d.c,"Lag.s",2], sens.inp, sub.arr[d.c,
"CurrState.v",2], sub.arr[d.c, "Ref.s",2], t.c, end.inp, sub.arr[d.c, "Appr.s", 2]))

###viii. Motivational value, m, for each consequence, j
####1. EU for each subordinate goal
sub.arr[d.c,"EU.v",c(1:2)]<-c((sub.arr[d.c, "Valence.v",1]*sub.arr[d.c, "Expect.v",1]),
                   (sub.arr[d.c, "Valence.v",2]*sub.arr[d.c, "Expect.v",2]))

####2. MV
#Conseq 1: Both succeed
sub.arr[d.c,"MVConseq1.v",c(1:2)]<-
(sub.arr[d.c,"EU.v",1]*conseq.mat[1,"BothSuccessQ.s"])+(sub.arr[d.c,"EU.v",2]*conseq.mat[2,"
BothSuccessQ.s"])

#Conseq 2: Both fail
sub.arr[d.c,"MVConseq2.v",c(1:2)]<-
(sub.arr[d.c,"EU.v",1]*conseq.mat[1,"BothFailQ.s"])+(sub.arr[d.c,"EU.v",2]*conseq.mat[2,"Bot
hFailQ.s"])

#Conseq 3: Goal 1 succeed
sub.arr[d.c,"MVConseq3.v",c(1:2)]<-
(sub.arr[d.c,"EU.v",1]*conseq.mat[1,"Sub1SuccessQ.s"])+(sub.arr[d.c,"EU.v",2]*conseq.mat[2,"
Sub1SuccessQ.s"])

#Conseq 4: Goal 2 success
sub.arr[d.c,"MVConseq4.v",c(1:2)]<-
(sub.arr[d.c,"EU.v",1]*conseq.mat[1,"Sub2SuccessQ.s"])+(sub.arr[d.c,"EU.v",2]*conseq.mat[2,"
Sub2SuccessQ.s"])

#Scaled MVs
sub.arr[d.c, c("MVConseq1Sc.v", "MVConseq2Sc.v", "MVConseq3Sc.v",
"MVConseq4Sc.v"), c(1:2)]<-c(sub.arr[d.c, c("MVConseq1.v", "MVConseq2.v",
"MVConseq3.v", "MVConseq4.v"), 1]/max(sub.arr[d.c, c("MVConseq1.v", "MVConseq2.v",
"MVConseq3.v", "MVConseq4.v"), 1]), sub.arr[d.c, c("MVConseq1.v", "MVConseq2.v",
"MVConseq3.v", "MVConseq4.v"), 2]/max(sub.arr[d.c, c("MVConseq1.v", "MVConseq2.v",
"MVConseq3.v", "MVConseq4.v"), 2]))
sub.arr[is.nan(sub.arr)]<-0
sub.arr[is.infinite(sub.arr)]<-0

if(sub.arr[d.c, "Valence.v", 1] == 0 & sub.arr[d.c, "Valence.v", 2] == 0) {
  t.c<-end.inp
}
```

```
  if(t.c < end.inp) {
    #3. Decision
    pref.c<-0
    while((-thresh2.inp) < pref.c & pref.c < thresh1.inp) {

      d.row.c<-d.row.c+1
      s.c<-s.c+1

      decision.mat[d.row.c, c("Decision", "Sample", "Time")]<-c(d.c, s.c, t.c)

      ##a. Momentary attractiveness, A, for each action
      decision.mat[d.row.c, c("MA1.v", "MA2.v")]<-
c(sample(x=sub.arr[d.c,c("MVConseq1Sc.v", "MVConseq2Sc.v", "MVConseq3Sc.v",
"MVConseq4Sc.v"),1], size=1, prob=conseq.mat[1,c("BothSuccessW.s", "BothFailW.s",
"Sub1SuccessW.s", "Sub2SuccessW.s")]),
                              sample(x=sub.arr[d.c,c("MVConseq1Sc.v",
"MVConseq2Sc.v", "MVConseq3Sc.v", "MVConseq4Sc.v"),2], size=1,
prob=conseq.mat[2,c("BothSuccessW.s", "BothFailW.s", "Sub1SuccessW.s",
"Sub2SuccessW.s")]))

      ##b. Preference
      if(s.c > 1){
        pref.c<-round((decision.mat[d.row.c-1, "Pref.v"] + (decision.mat[d.row.c, "MA1.v"] -
decision.mat[d.row.c, "MA2.v"])), 2)
      } else {
        pref.c<-round((decision.mat[d.row.c, "MA1.v"] - decision.mat[d.row.c, "MA2.v"]),2)
      }

      decision.mat[d.row.c, "Pref.v"]<-pref.c

      sub.arr[d.c, "FocalGoal.v",c(1:2)]<-ifelse(decision.mat[d.row.c, "Pref.v"] >= thresh1.inp, 1,
ifelse(decision.mat[d.row.c, "Pref.v"] <= -(thresh2.inp), 2, 0))

      if(sub.arr[d.c, "FocalGoal.v",1] > 0 & ((-thresh2.inp) >= pref.c | pref.c >= thresh1.inp)) {

        t.c<-(t.c+sub.arr[d.c, "Lag.s", sub.arr[d.c, "FocalGoal.v",1]])

      }

    }

  }


  #Clear out s.c for next decision
```

```
    s.c<-0

  }

  sub.arr<-sub.arr[c(1:d.c),,]
  sup.arr<-sup.arr[c(1:d.c),,]
  decision.mat<-decision.mat[c(1:d.row.c),]

  output<-list("sub"=sub.arr, "sup"=sup.arr, "decision"=decision.mat)
  return(output)

}
```

Appendix B

HMGPM Simulation ‘R’ Code

```
require(plyr)

cond<-rep(1:18, each=50)
ind<-c(1:900)
attn<-c(rep(1, 500), rep(c(2, 1), each=150), rep(3, 50), rep(1, 50))
multi1<-c(rep(0, 200), rep(1, 100), rep(0, 150), rep(1, 50), rep(0, 100), rep(1, 50), rep(0, 100),
rep(1, 50), rep(0, 100))
multi2<-c(rep(0, 200), rep(1, 100), rep(0, 150), rep(1, 50), rep(0, 100), rep(1, 200), rep(0, 100))
superNum<-c(rep(2, 150), rep(1, 50), rep(2, 200), rep(1, 50), rep(2, 50), rep(1, 50), rep(2, 350))
need1<-c(rep(25, 800), rep(30, 50), rep(25, 50))
need2<-c(rep(25, 150), rep(c(0, 25),  each=50), rep(15, 100), rep(25, 50), rep(0, 50), rep(25, 50),
rep(0, 50), rep(25, 100), rep(15, 150), rep(5, 50), rep(15, 50))
inst11<-c(rep(c(.1, .5, 1), each=50), rep(.5, 200), rep(1, 150), rep(.5, 200), rep(0, 50), rep(1,
150))
inst12<-c(rep(0, 200), rep(.5, 100), rep(0, 150), rep(1, 50), rep(0, 100), rep(.5, 50), rep(0, 50),
rep(.5, 100), rep(0, 100))
inst21<-c(rep(0, 150), rep(.5, 150), rep(0, 100), rep(.5, 150), rep(0, 50), rep(.5, 200), rep(0, 100))
inst22<-c(rep(c(.1, .5, 1), each=50), rep(0, 50), rep(.5, 200), rep(0, 50), rep(.5, 50), rep(0, 50),
rep(.5, 350))
deadline<-c(rep(50, 500), rep(76, 150), rep(50, 250))

conds<-cbind(cbind(cbind(cbind(cbind(cbind(cbind(cbind(cbind(cbind(cbind(cbind(cond, ind),
attn), multi1), multi2), superNum), need1), need2), inst11), inst21), inst12), inst22), deadline)

sim.sub<-list()
sim.sup<-list()
sim.dec<-list()

for(i in 1:900) {
  results<-hmgpm(conds[i,1], conds[i,2], conds[i,3], conds[i,4], conds[i,5], conds[i,6], conds[i,7],
conds[i,8], conds[i,9], conds[i,10], conds[i,11], conds[i,12], conds[i,13])

  results.sub<-as.matrix(do.call("rbind",alply(results$sub, .margins=3)))
  SubGoal<-rep(c(1,2), each=max(results.sub[,"Decision"]))
  results.sub<-cbind(results.sub, newColumn=SubGoal)
  colnames(results.sub)[33]<-"SubGoal"
  sim.sub[[i]]<-results.sub

  results.sup<-as.matrix(do.call("rbind",alply(results$sup, .margins=3)))
  SupGoal<-rep(c(1,2), each=max(results.sup[,"Decision"]))
  results.sup<-cbind(results.sup, newColumn=SupGoal)
  colnames(results.sup)[9]<-"SupGoal"
```

```
  simF.sup[[i]]<-results.sup

  results.dec<-results$decision
  sim.dec[[i]]<-results.dec
}

sim.sub.full<-do.call(rbind, sim.sub)
sim.sup.full<-do.call(rbind, sim.sup)
sim.dec.full<-do.call(rbind, sim.dec)
```

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