Hypothetical thinking in adolescence:

Its nature, development, and applications

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It is the mark of an intelligent mind to be able to
entertain an idea without necessarily accepting it. -- Aristotle

Classic theories of human development characterize adolescence as a period of an awakening of new, powerful, and pervasive abilities and talents. Such was the claim of G. Stanley Hall (1904, cited in Grinder 1967, p. 358) who noted that "adolescence is… the only point of departure for the superanthropoid that man is to become". Similarly, Piaget (1972; Inhelder & Piaget, 1958) held that adolescence is the period in which new and powerful forms of reasoning emerge. These abilities and talents are so novel that both G. Stanley Hall (1904; and, see Grinder, 1969) and Jean Piaget (Piaget, 1972; Inhelder & Piaget, 1958) identify a context and a period of time for the nascent adult to cultivate these skills. These abilities are so encompassing that they are thought to result in fundamental changes in how teens think, forever transforming their views of themselves, others, and the world (Erikson, 1968; Kohlberg, 1984; Selman. 1980).

In this chapter I explore hypothetical thinking as one of the novel, powerful, and pervasive achievements of adolescence that fundamentally impacts and alters them. Specifically, I examine the nature of hypothetical thinking, its process of development, and applications in the life of adolescents. Hypothetical thinking places a premium on what Aristotle cited as the mark of an intelligent mind – the ability to entertain an idea without necessarily accepting it. Central to hypothetical thinking is the ability to assume, suppose, or stipulate as true claims that may conflict with what is accepted as true about the world. The ability to treat ideas *as if* they were true is implicated in a variety of significant human endeavors, from systematically testing a hypothesis, logically reasoning about an argument, constructing a possible world, regretting one's life choices, or reacting to a pretend enactment. These examples point to one of the most curious things about hypothetical reasoning. It is implicated in spontaneous and playful pursuits such as pretense and in formal and serious intellectual activities such as logic or science.

1. The Nature of Hypothetical Thinking

Hypothetical thinking is defined as the ability to reason about alternatives to the way the world is believed to be (Rescher, 1961, 1964; St. B. T. Evans, 2007). The definition highlights three general components: recruiting the imagination, making inferences about imagined states of affairs, and interpreting the real world consequences of the states imagined. Hypothetical thinking as the process of generating hypotheses, arguments, fictions, alternative event sequences, or pretend scenarios involves the *imagination.* The imagination is used to create alternatives to reality that are distinguished from reality. These alternative states of affairs may be represented in mental models and are created by imagining variations or mutations of accepted beliefs about reality, thereby contravening those beliefs.

Hypothetical reasoning also requires making *inferences* about the imagined states of affairs. For example, outcomes can be inferred from the constructed mental model of an alternative world, with its belief contravening claims. The inferential process may range from formally drawing conclusions from premises whose truth status is either known to be false, unknown, or indeterminate (Rescher, 1961; 1964) or by literally running the mental model of an alternative world through a process known as *mental simulation*. Mental simulations exploit real world causal knowledge to actually put into motion the conditions specified in the mental model of an alternative world and then to read off its outcome (Kahneman & Tversky, 1982). However it is accomplished, the inferential process in hypothetical reasoning provides a basis to understand possible outcomes of alternative worlds.

Finally, considering alternatives to the way the world is believed to be involves *interpretations* of the differences between the worlds believed to be true and the imagined alternative one. At very least, this means keeping track of differences between the claims made

about the two different worlds, but it may also mean that the outcome of the alternative world is used to understand the meaning and significance of events that do occur. For example, discovering how an alternative action may have led to a better outcome than the one resulting from a person's actual actions may result in the person experiencing regret (Landsman, 1998). Alternatively, discovering how the alternative actions of a person would have made no difference in a negative outcome may relieve the person of responsibility for the outcome. In both cases, actual events are evaluated in light of imagined alternative ones which might have occurred.

2. Formal Operations and Hypothetical Reasoning

The central thesis of the chapter, that hypothetical reasoning is a transformative ability acquired in adolescence, is not new. Piaget made this point over 50 years ago and revisited this topic over the years (1972; 1987; Inhelder & Piaget, 1958). According to Piaget (1972), adolescents acquire the ability to form hypotheses about reality and test them out. Such an ability, he claimed (Piaget, 1972, p. 3), is "the principle novelty of the period" and is "a decisive turning point because to reason hypothetically and to deduce consequences that the hypotheses necessarily imply (independent of the truth or falsity of the premise) a formal reasoning process." Inhelder and Piaget (1958) understood hypothetical reasoning as reflecting the operation of an underlying formal hypothetico-deductive system which allows the adolescent to anticipate *all* logical possibilities in a situation. Inhelder and Piaget (1958) documented both the underlying formal system and the actual reasoning of children and adolescents on tasks requiring them to identify factors influencing various physical phenomena (e.g., buoyancy, pendulum periods, material flexibility, acceleration, chemical reactions). Only adolescents approached the tasks by systematically generating and testing out hypotheses rather than just subjectively acting on the apparatus or exploring empirical relations operating in the apparatus. Piaget (1972) later

recognized that hypothetical reasoning does not emerge fully formed and universally applicable in adolescence, but is demonstrated first in domains of personal interest and relevance. Even later, Piaget (1987) further acknowledged that the ability to entertain possibilities is not just the product of the growth of reasoning from childhood to adolescence, but also the motor of that development as children expand their horizons about the widening set of possibilities out of which reality springs (also see Gallagher & Reid, 2002).

To Piaget what is unique about adolescence is that the imagination becomes under the control of an abstract logical system, giving hypothetical reasoning the status of an objective and systematic tool by which to consider possibilities. Young children's reasoning about possibilities is subjective and unsystematic, derived from and limited to their real world knowledge, beliefs, and activities. However, adolescents become able to reason objectively and systematically about possibilities, resulting in them inverting the relationship between the real and possible such that there is a "subordination of the real to the realm of the possible" (Piaget, 1972, p. 3).

Consider combinatorial reasoning, the ability to generate all possible combinations of *n* elements. When *n* is small, even young children can work though all combinations using their domain knowledge, experience, or trial and error (English, 1993). But as the value of *n* increases, it becomes more difficult to compute all combinations without an ability to think logically about possibilities (Bearson & Dimant, 1990). Combinatorial reasoning is among the first formal operations skills acquired (Broughton, 1983; Robarge & Flexer, 1979), reflecting adolescents' grasp of the logic underlying possibilities and laying the foundation for the acquisition of other logico-mathematical reasoning skills (Robarge & Flexer, 1980; Moshman, 1998).

A number of criticisms have been leveled at Piaget's claim that adolescents become capable of logical (i.e., objective and systematic) reasoning about possibilities. The first is that

even adults struggle to reason hypothetically in this manner. It is difficult for many adults to reason about possibilities without being inappropriately influenced by what they know, believe, or desire about a situation. From this perspective, hypothetical thinking is hard work, requiring the careful and conscious regulation of available beliefs, knowledge, and desires in order to reason about possibilities in an unbiased manner (Kuhn, 2001; St. B. T. Evans, 2007). On the other hand, hypothetically thinking can be as easy as child's play. Young children's pretend play has been characterized as creating and reasoning about alternative worlds (Carruthers, 2002; Nichols & Stich, 2000), which taps the same ability to reason about possibilities as any other form of hypothetical or creative thinking (Carruthers, 2002). Both these criticisms assert that hypothetical thinking, in the form of objective and systematic reasoning about possibilities, is neither acquired nor perfected by adolescents, undermining the central thesis of the chapter. I review each of these criticisms with an eye to understanding what it is about hypothetical reasoning which is uniquely acquired during adolescence.

3. Hypothetical Thinking as Child's Play

While pretending that an empty cup is full of tea, a two year old child turns over the cup, spilling its imaginary contents onto a teddy bear. When asked, the toddler describes the cup as now being empty and proceeds to clean up the imaginary mess with a rag. Such a scenario was documented by Harris and Kavanaugh (1993) as part of their exploration of the extent to which 2 year olds' pretend play involves creating and reasoning about imagined alternatives to the way the world is. Harris and Kavanaugh, like others, were convinced of the capacity for the youngest of children to reason according to the three characteristics of hypothetical thinking previous described: recruiting the imagination, making inferences about imagined states of affairs, and interpreting the real world consequences of the states imagined. First, young children use their

imagination to create alternatives to the way the world is believed to be. In the scenario documented above, young children treated an empty cup *as if* it were filled with water. Second, inferences were readily made regarding the consequences of the imagined features of the cup. The pretending child correctly inferred not only that a mess would result if the cup full of water were overturned but also correctly inferred precisely where the mess would be. Finally, the child kept track of the differences between the claims made about a pretend and real world[1] and made sure that there were *no* consequences for beliefs about the real world of entertaining an imagined pretend world. This latter point is important, as profound conceptual confusion results if the pretend world influences children's interpretation of real world beliefs (Leslie, 1987). For example, conceptual chaos results if pretending that a banana is a telephone alters a child's real world concept of bananas to include the features and functions of telephones.

Young children's ability to both generate alternatives to reality and appreciate their implications and consequences has led many to characterize pretense as a form of hypothetical reasoning in which children act consistently with respect to pretend claims (Amsel, Bobadilla, Coch, & Remy, 1996; Amsel, 2000; Harris, 2000; Harris & Kavanaugh, 1993; Leslie, 1987; Lillard, 2001; Nichols & Stich, 2000; Perner, 1991). This is a completely different characterization of pretense than Piaget's (1962). For Piaget (1962), pretense is a form of egocentric and maladaptive thinking in which reality is largely assimilated to the idiosyncratic and subjective desires and wishes of the child, with no corresponding alteration of mental structures to accommodate reality (see Harris, 2000). The claim that pretense is intrinsically a form of hypothetical reasoning challenges Piaget's account of the very trajectory of cognitive development itself. To Piaget, development proceeds from the subjective and idiosyncratic

[1] Claims about the pretend world are designated a *pretend claims* and claims about the real world are designated as *belief claims*.

forms of thinking represented by pretend play to the objective and unbiased forms of thinking represented by formal reasoning about possibilities. The Piagetian account of development collapses onto itself, if in pretend play young children can demonstrate their ability to use hypothetical thinking as an objective and systematic tool for understanding possibilities.

Although there is agreement that pretend play implicates a form of hypothetical reasoning, there is less agreement on the kind of achievement it signifies. Leslie (Friedman, & Leslie, 2007; Leslie, 1987) proposes that belief claims are encoded in a first-order representational system which takes input from the world, such as the clam that *a cup is empty*. Pretend claims are encoded in a metarepresentational system that takes propositions from the first ordered system after they are copied, edited, and attached to an agent who is identified as pretending. So a child pretending the empty cup is full of water represents that *I* (agent) *pretend* (operator) *that the "empty cup contains water"* (copied and edited first order proposition).

Others propose that pretense involves an agent treating pretend claims *as if* they were true, requiring no metarepresentation of an agent or the pretend claims. One proposal is that children represent the belief and pretend claims together in a counterfactual proposition that is flagged or marked as pretend (Harris & Kavanaugh, 1993; Nichols & Stich, 2000). For example, Nichols and Stich (2000) propose that a pretending child represents the proposition *this [empty] cup contains water,* in a *possible world box,* which is a special cognitive workspace that marks the proposition and related ones as counterfactual. Another proposal is that children represent relevant belief and pretend claims in distinct models and then coordinates the two (Lillard, 2001; Perner 1991; Perner, Baker, & Hutton, 1994). For example, Perner (1991) assumes two distinct cognitive models of a pretend situation, one encoding beliefs claims (e.g., REAL: *this cup is empty*) and the other encoding pretend claims (HYPOTHETICAL: *this cup contains water*).

In research addressing the cognitive representations underlying pretense, Amsel et al. (1996) had 3-year-olds identify the actions (combing), and the actual (a fork) and pretend (a comb) identities of objects used in an episode of pretense (pretending to comb hair with a fork). These identifications were made as children observed another's pretense or recalled their own initial pretense activities in multiple pretense scenarios. Although they had little difficulty identifying the actions performed, the children were more likely to correctly identify the actual than the pretend identity of the object (also see Albertson & Shore, 2008 and Wyman, Rakoczy, & Tomasello, 2009). Interestingly, there was no contingency in correctly identifying the objects' identities, as would be expected if children form a single representation encoding together both belief and pretend claims. The findings were interpreted as suggesting that underlying young children's pretense is their representation of a pretend and the real world in distinct models (Amsel et al., 1996; Amsel & Smalley, 2000).

There is no reason to think that only two models of the world exist at any given time. Weisberg and Bloom (2009) found that children may form multiple distinct models for different pretend worlds. They found that preschoolers who created a particular pretend identity for an object in one pretend scenario would not spontaneously use the same object for the same pretend function in a second pretend scenario that was occurring simultaneous to or after the first scenario. It seems that children form boundaries between multiple pretend worlds, a finding replicated in their understanding of fictional worlds (Skolnick & Bloom, 2006).

It appears that pretense involves some but not all cognitive skills that are central to hypothetical thinking. The hypothetical thinking skills implicated in pretense includes creating a model of an alternative to world that is distinguished from real world. The boundary between the worlds is porous enough for children to *import* real world knowledge when necessary into the

pretend world. But the boundary is largely impermeable to the child moving in the other direction so that real world beliefs and knowledge remains unaffected by engaging in pretense.

However, pretense does not seem to require two critical components of hypothetical thinking. First, the form of hypothetical reasoning implicated in children's pretend play need not be objective and systematic in the sense of children creating a realistic or serious *possible* world. Instead, children's pretend worlds may be fanciful, reflecting a process of hypothetical thinking that is subjective and idiosyncratic. Although a child may pretend that make-believe water pours from a glass in the pretend world in much the same way as it does in the real world, there is no guarantee that the child will pretend that the water will have all and only those properties it is believed to have in the real world. Children may not feel compelled to insure that all features and processes of the real world are present in the pretend world. Second, the form of hypothetical thinking in pretend play does not require that children's understanding of the real world is affected by or subordinated to the pretend one. The evidence suggests that children readily keep the pretend and real worlds separate (Woolley, 1995, 1997). Although there are cases of "leakage" of the pretend world into the real world (Bourchier & Davis, 2002), such cases are best described as local and temporary failures rather than general and long-term vulnerabilities.

Although not tapped by pretend play, children may nonetheless have fledging abilities to objectively and systematically create alternative possible worlds to reality which are used to understand reality. In one line of research, children as young as 2 years old have been shown to can make valid deductions on counterfactual syllogism tasks simply by framing the counterfactual premise as make-believe (Amsel, Trionfi, & Campbell, 2005; Dias & Harris, 1988, 1990; Markovits & Vachon, 1989; Richards & Sanderson, 1999). For example, Amsel et al. (2005) found that when invited to *pretend* a make-believe world in which dogs meow, and

introduced to Rover the dog while still pretending, 6-year-olds tended to validly infer that Rover meows. Forty percent of the 6-year-olds gave logically valid answers on all three make-believe trials, which is significantly above chance responding. The findings suggest that children are able to use logic to objectively and systematically guide inferences regarding the pretend world.

To test children's limitations to reason logically in a Make-believe condition, Amsel et al. (2005) included a Hypothetical condition which invited children to reason logically about counterfactual premises in an analogue of a possible world. In the Hypothetical condition, participants were invited to *imagine* what the real would be like if dogs meow, then while they were still imagining, introduced participants to Rover the dog, and asked whether Rover meows. Only 17% of the six-year-olds gave logical answers on all 3 of the hypothetical trials, a percentage no different than expected by chance and significantly lower than the percentage consistently making valid judgments in the Make-believe condition. A 10-year-old group also demonstrated a disparity between the Hypothetical and Make-believe conditions but was erased among college students (see Figure 1). The results suggest that the children in the two younger groups have difficulty using logic to reason objectively and systematically about a counterfactual premise in a serious *possible* world compared to a fanciful *pretend* world.

Participants in Amsel et al. (2005) were also asked about the features of the alternative creatures they created in the Make-believe and Hypothetical conditions. Participants were asked whether the alternative creatures they imagined had features of the object and subject of the counterfactual claim. In the case of meowing dogs, participants were asked about whether the creature has two features of dogs (e.g., growls and wags its tail) and two features of cats (e.g., purrs and eats mice). Generally, participants' syllogism performance was consistent with their attribute judgments. Only participants who consistently made logically valid inferences in the

Make-believe and Hypothetical conditions were selective about the features of their creatures. They affirmed more features of the objects (dog) than subjects (cat) of the counterfactual claim, seemingly reflecting on and evaluating the features that a hybrid animal might actually possess.

The importance of critical reflection on judging possibilities has recently been confirmed in a series of studies by Shtulman (2009; Shtulman & Carey, 2007). Despite an ability to distinguish real from pretend and ordinary from impossible states of affairs, children have difficulty distinguishing between improbable and impossible ones, denying that each is possible. Shtulman explains that children's modal judgments are based on whether they had first hand experiences of the events. In contrast, adults make modal judgments of impossibility by critically reflecting on and evaluating their experience of events against their causal knowledge to decide whether the event is in fact impossible or just improbable.

The role of critical reflection and evaluation of possible worlds is a central concern in another line of research on children's abilities to objectively and systematically think hypothetically. Generally, even young children have been shown to correctly answer future hypothetical questions of the sort, *what would happen if…* (Riggs, Peterson, Robinson, & Mitchell, 1998; Robinson & Beck, 2000). Children create and run a mental simulation in order to understand the future of a given state of affairs. However, they may not understand that for a given state of affairs there may have been an alternative possibility which could have occurred instead. This latter ability has been tested in counterfactual reasoning research in which children are assessed for their ability to infer alternative possible event sequences, given hypothetical changes to the antecedent or consequence of the actual sequence (Amsel & Smalley, 2000; Guajardo, Parker, & Turley-Ames, 2009; Harris, German, & Mills, 1996; Riggs & Peterson, 2000; Riggs et al., 1998; Robinson & Beck, 2000). For example, Amsel & Smalley (2000)

report a card game in which preschoolers and adults were given two face-down cards and had to choose one to turn over. If participants turned over a card with the highest number, they won the hand and earned stickers or small gifts. On trials where the participant turned over a losing card, they were invited to turn over the alternative card. On these trials, preschoolers, like adults, could readily understand that they although they lost the hand, they would have won the hand if only they had turned over the alternative card. This finding suggests that children can objectively and systematically create possible worlds which have consequences for understanding the causal role of events in the actual event sequences.

Beck, Robinson, Carroll, & Apperly (2006) and Rafetseder, Cristi-Vargas, and Perner, (2010) have questioned whether all appropriate controls were exercised on these counterfactual reasoning tasks. Beck et al. (2006) argued that perhaps children's responses on counterfactual reasoning tasks may not actually reflect an understanding of possible states of affair. In Beck et al. (2006, Study 2), preschoolers were presented with a slide in which a toy could take one of two routes. After seeing a toy take one route down the slide, they were asked two different questions. Although they could readily answer a question about alternative *outcomes*, typically requested in standard counterfactual tasks (*What if the toy had gone the other way, where would it be*?), they had more difficulty answering an open counterfactual question regarding alternative *possibilities* (*Could the toy have gone anywhere else?*). Beck et al. concluded that young children do not treat alternatives outcomes as possibilities, which appears to require critically reflecting on different outcomes to appreciate their status as alternative possibilities.

Rafetseder et al. (2010) similarly found that previous research has overestimated young children's counterfactual reasoning competence. They designed a task that minimized children's ability to use knowledge about general conditional relationships to answer the specific

counterfactual questions without ever constructing a possible world. For example, perhaps children in Amsel et al.'s (2000) card game could answer counterfactual questions by using their general conditional knowledge about the game (if a high card is turned over, you win the game) without actually constructing an alternative possible world in which they turned over the other card. Rafetseder et al. (2010) found that adolescents and adults were able to reason counterfactually in conditions minimizing the use of general conditionals to answer counterfactual questions, although 6 year-olds showed only a fledgling ability to do so.

The later onset view of counterfactual reasoning was also reported in the studies of the counterfactual emotion of regret. Regret is a negative counterfactual emotion based on appreciating that better outcomes would have been realized if only one had acted differently (Landman, 1993; Gilovich & Medvec, 1995). For example, consider a scenario that Guttentag and Ferrell (2004) presented to 6-year-olds, 7-year-olds, and adults.

> Bob and David both ride their bikes to school each morning. There are two paths that go to school around a pond. You can ride along the red path or you can ride along the yellow path. Everyday, when Bob gets to the pond he goes along the red path around the pond. Today, Bob took his usual way to school along the red path. Unfortunately, today a tree fell across the red path. Bob hit the branch with his bike, fell off his bike, was hurt and was late for school. Everything on the yellow path was fine. David always goes along the yellow path. However, today David decided that instead of going along his usual yellow path to school he was going to ride along the red path. David also hit the tree, fell off his bike, was hurt and was late for school. Who would be more upset about deciding to ride along the red path around the pond that day?

Adults and 7-year-olds judged that David feels greater regret despite both protagonists being in exactly the same state of having been hurt by biking on the red route. David was judged as feeling more regret presumably because the accident is understood in light of a normally-taken alternative route which would have avoided the accident. That is, reality is understood in light of possibilities that could (and perhaps should) have occurred, but did not. However, the group of 6-year-olds did not judge that David felt worse than Bob. The pattern of results was explained by the failure of young children to relate actual states of affairs to counterfactual ones. Even if children create alternative possible worlds, they are not used to interpret actual event sequences.

This explanation was explicitly tested by Amsel and Smalley (2000), who used the card game task described previously. As noted, young preschoolers and adults readily recognized conditions in which they would have won the card game by engaging in alternative actions (i.e., turning over the other card). However, only adults were affected by discovering the value of the unchosen card. Adults but not preschoolers showed a change in their feelings recorded on a simple scale (ranging from very happy to very sad) before and after they discovered the alternative action would have resulted in a different outcome. This failure by children to relate factual and counterfactual states of affairs has been replicated by others (Beck & Crilly, 2009; McCloy & Strange, 2009) suggesting that young children lack a critical component of hypothetical thinking: the ability to interpret reality in light of possible alternatives to reality.

Young children's pretend play appears to include some important components of hypothetical thinking. They can readily create an alternative world and think logically with respect to it. Indeed, they may be able to create multiple imaginary worlds and keep each conceptually and ontological distinct (Skolnick & Bloom, 2006; Weisberg and Bloom, 2009). But these alternative imaginary worlds are not possible worlds by which reality can be

understood. The general point -- that young children do not appreciate imagined alternative worlds as *possible* ones -- is echoed in the logical and counterfactual reasoning literatures. Moreover, research on regret reasoning suggests that the alternative worlds created by older children do not affect their evaluation of actual events. Children's challenge in creating and reasoning about serious *possible* worlds may lie in their ability to critically reflect on and evaluate the content of their alternative worlds. This was suggested from children's difficulty in reasoning logically about hypothetical premises, which was related to the unconstrained representations of the alternative worlds they created and modal reasoning literature, which points to children's lack of reflection to distinguish possible from impossible events.

4. *Hypothetical Thinking as Hard Work*

Although it is clear that young children have some of the component skills to reason hypothetically, the present section addresses whether adolescence is a time that component skills of hypothetical thinking are fully coordinated to function as an effective tool by which to understand reality in light of possibilities. If this view is correct then adolescents should demonstrate the ability to objectively and systematically entertain, reason about, and interpret reality in light of possibilities across a variety of contexts and situations. Yet it is precisely this ability that appears to be a challenge to not only adolescents, but also adults. Even examining performance on complex combinatorial tasks as an index of objective and systematic reasoning about possibilities, adolescents and adults are challenged depending on the content, and demands of the task (Fischbein & Gazit, 1988; White, 1985).

In this section, I review literatures that identify challenges that hypothetical reasoning poses to adolescents and adults. The first literature addresses the development and regulation of counterfactual emotions of regret. This work identifies regulatory challenges posed by directing

the hypothetical thinking underlying regret, including limiting the influence of actual beliefs, knowledge, and desires. The second literature addresses the development and regulation of hypothesis testing, which involves treating variables as possible causes or causal hypotheses of an outcome. Adolescents and adults are limited in entertaining theoretical beliefs as potentially false and in consciously coordinating theoretical beliefs and evidence. In both cases, adolescents' and adults' regulatory difficulties undermine their ability to effectively use hypothetical reasoning as an objective and systematic tool to understand reality in light of possibilities.

Returning to hypothetical reasoning and the experience of regret, consider being told a story about a protagonist choosing between one of two boxes and winning a *good* gift. But, in the box not chosen, there was a *great* gift, which the protagonist could have had if only she had chosen the alternative box. The story continues with the protagonist peeking into the box not chosen and discovering the better gift. It is easy to judge that the protagonist felt regretful that she had not chosen the other box, reflecting an understanding that receiving the good gift is only one possible way reality could have turned out. Such stories were presented to preschoolers, children, young adolescents, and adults (Guttentag & Ferrell, 2008). Everyone but the preschoolers judged that the protagonist felt regret, replicating previous work described above of the difficulty young children have with experiencing regret or understanding when it occurs. However, in another set of questions, Guttentag and Ferrell (2008) found that only a majority of adults were able to appreciate that a protagonist would want to avoid discovering the content of an unchosen box, thereby anticipating and seeking to avoid regret. Moreover, only the adolescent and adult groups expressed the hope that the unchosen box was empty, again anticipating and seeing to avoid regret. The findings suggest that although children understand the conditions and contexts that result in regret, only adolescents begin to anticipate these conditions and contexts

and think through ways to avoid regret. The hypothetical thinking necessary to *experience* regret is made that much more challenging when the regret is *anticipated*.

Even young college students' ability to anticipate regret can be seen as fledging when the conditions put participants' desires into conflict with their ability to objectively and systematically reason hypothetically. Amsel, Cottrell, Sullivan, & Bowden, (2005) assessed young adolescents (11-year-olds) and college students' ability to make decisions which avoid anticipated regret. Participants read about a protagonist making an everyday decision that put into conflict what the protagonist (and participants) would want to do with what they ought to do (i.e., studying for an exam or going to a movie with friends; buying a valuable gift for friend or for oneself). Participants read a one positive and one negative outcome for each option which were identified as equally likely and ordered from most to least emotionally positive for the protagonist. Participants were asked which decision should be made so that the protagonist would avoid regret, no matter how the decision turned out.

Given the emotional ranking of possible outcomes, a decision that would ensure the avoidance of regret is the option associated with the most negative outcome. When the most negative outcome was associated with the undesired option (e.g., studying for the exam but feeling left out from one's friends) a large majority of participants anticipated and avoided regret by choosing the desired option (e.g., going to a movie with friends). But when the most negative outcome was associated with a desired option (e.g., buying a valuable gift for oneself but disappointing a friend with no gift), significantly fewer college students and preteens avoided anticipated regret by choosing the undesired option. The preteens and college students were no different in their judgments, demonstrating the general influence of beliefs and desires on participants' ability to make decisions that anticipate and avoid regret.

Prior to being given the protagonists' rankings and making a decision, participants were asked to complete three component skills necessary to create the rankings and make a final regret-based decision. These skills include: a) generating possible positive and negative possible outcomes associated with each decision option, b) anticipating ones' own feelings associated with each possibility being realized and c) rank ordering those outcomes in light of anticipated feelings. In each case, the adolescent group performed less methodically, less systematically, and in a more biased manner than the college students. Compared to the college students, the young adolescents generated fewer negative potential outcomes for desired options, anticipated the negative outcomes to desired options to be less affectively negative, and were more biased in more negatively rank ordering undesired than desired outcomes. The adults showed some, but substantially less, influence than the preadolescents of the desirability of options on their component abilities to anticipate and avoid regret.

The challenge in hypothetically thinking about regret goes beyond initially experiencing or anticipating regret, to managing or regulating the emotion (Zeelenberg & Pieters, 2007). Generally speaking, once initiated, regret may be difficult to turn off, even if one wants to, and may lead to negative outcomes. Unregulated regret is related to insomnia (Schmidt & Van der Linden, 2009), general distress (Roese, Epstude, Fessel, Morrison, Smallman, Summerville, et al., 2009), and poor coping after the end of a relationship (Saffrey & Ehrenberg, 2007).

The regulatory challenge posed by hypothetical thinking is sometimes so profound as to cause distress. A colleague who teaches *Psychology of Women and Gender* requires an assignment in which students are asked to imagine that they are gay and write a letter coming out to their parents. A week before the assignment was due, the professor received the following email from a student in the class:

> As I read through the assignment and saw what it entails I began to feel very uncomfortable. I'm sorry but I truly cannot write these letters, thus I cannot do this assignment. It goes against everything inside of me. I understand that it is just an assignment, but to me it is more than that. By doing it I would have to put myself in that position by turning my thoughts to it, which will contradict everything I have been taught: that I believe. I do not want to put these thoughts in my mind for any reason.

Personal beliefs and values may not only *bias* hypothetical thinking, they may *stop* it cold! This student is not alone in being unwilling to entertain hypothetical possibilities because they conflicted with closely held the beliefs and values. Politicians refuse to answer hypothetical questions all the time in fear of revealing their closely held values and beliefs (Kensley, 2003). Perhaps it is not surprising that such refusals occur when one is asked to think hypothetically about emotionally or politically salient issues. But the evidence suggests that hypothetical thinking is biased even in relatively emotionally cold contexts. Kuhn, Amsel, & O'Loughlin (1988) demonstrated that adolescents and adults were biased when evaluating evidence for variables about which they held prior beliefs. In this research, participants reviewed a series of instances of potential causal variables associated with a positive or negative outcome. Two variables, one believed causal and one non-causal, were consistently associated with the positive outcome, suggesting that either one or both together could be causally related to the outcome.

Participants were to treat each variable as a possible cause of the outcome and test each against the data. But, instead of treating variables *as if* they were possible causes, some participants just reiterated their beliefs that the variables were causal or non-causal. This failure to adopt a hypothetical attitude towards the variables was reflected in *belief-based* responses that melded theory and evidence into a single representation of "the way things are". Belief-based

responses decreased in frequency from childhood to adulthood but sporadic use of them remained prevalent among most adults. In other studies presented by Kuhn et al. (1988), participants were posed different forms of the test question to better clarify that prior beliefs were to be ignored and the variables treated as causal hypotheses. Although the procedure worked to reduce the prevalence of belief-based responses, it did not eliminate them, and age-related differences remained. Another way found to reduce belief-based responses was to use task content (laundry task vs. plant task) which elicited less strongly held prior beliefs. But participants still used available beliefs to respond to questions in a belief-based manner.

Even when a hypothetical attitude towards the variables was adopted and participants evaluate variables against the data, prior beliefs undermined an objective and systematic evaluation of the evidence. Notably, the indeterminacy of the evidence was ignored, and "evidence-based" responses were made in a biased manner, with the same patterns of data being interpreted differently for variables believed to be causal and non-causal. There were very few cases of identical evaluations of the causal status of the pair of variables receiving the same pattern of evidence even among adult groups.

Subsequent research over the past 20 years has thoroughly tested the Kuhn et al.'s (1988) account of the development of skills to coordinate theory and evidence (see Lehrer & Schauble, 2006; Zimmerman, 2000, 2007). One line of research has identified skills to *implicitly* evaluate and revise beliefs about multi-causal variables being acquired in childhood (e.g., Schulz & Bonawitz, 2007; Schultz, Gopnik, & Gilmore, 2007). These accounts of multi-causal inferences do not require conscious reflection on and coordination of hypothetical beliefs and evidence. These findings do not deny the importance of *explicit* theory-evidence coordination, which may be necessary to articulately defend judgments to others or oneself (Kuhn & Dean, 2004)

Although not all evidence evaluation tasks require explicit theory-evidence coordination, performance on tasks which do demonstrates age/education- and task-related variability (Lehrer & Schauble, 2006; Zimmerman, 2000, 2007). For example, Amsel & Brock (1996) minimized task demands compared to Kuhn et al. (1988) by presenting participants with multiple pieces of evidence for a single variable paired with an outcome. Instances of healthy or sick plants were associated with the presence or absence of a causal (sun) or non-causal (charm) variable. Children, adolescents, non-college educated adults, and college students held strong prior beliefs about the variables, which received the same patterns of evidence, so that variables believed causal and non-causal were both confirmed and disconfirmed. At each age group, participants additionally were randomly assigned to conditions which presented the same instances of evidence for variables as the standard control group, but also included missing instances of data with either the status of the variable missing, the status of the outcome missing, or both missing. After all the instances in a trial were reviewed, participants rated their certainty of the causal status of the variable on a 7-point scale (from very certain the variable is causal to very certain the variable is non-causal) and justified those judgments.

Two key results are relevant here. First, even the youngest children in the study were responsive to the evidence, despite holding contrary beliefs for some variables. The ratings of each age group suggest that they distinguished the patterns of data, confirming their sensitivity to the evidence. This sensitivity to the evidence was further demonstrated by participants' ratings of the causal or non-causal status of variables in the presence of instances of missing data. Causal certainty ratings in these conditions were the same as (adult and college groups) or lower than (children and adolescent groups) the control condition, which contained no missing data instances. The findings suggest that missing data were not treated as opportunities to project

prior beliefs onto incomplete data, as would be expected if participants were merely using their prior beliefs to interpret the data.

Second, all participants' judgments and justifications were affected by their prior beliefs. There was a linear increase by age and education in justifying causal judgments by referring to the evidence, replicating Kuhn et al. (1988). Also, all groups of participants differentially rated the causal status of variables believed causal and non-causal, despite the variables having been presented with the same evidence. The effect of prior beliefs on causal ratings was weakest among the college students and similar for the children, adolescents, and adults.

Hypothetical thinking skills underlie the ability to anticipate and regulate regret and to consciously entertain causal hypotheses and coordinate them with evidence. The skills involve the objective and systematic creation and evaluation of possible worlds and the interpretation of the real world in light of them. Armed with the ability to do so, reality is understood in light of possibilities, or as Piaget and Inhelder put it, reality becomes subordinated to possibilities. However, adults' processes of hypothetical thinking on these tasks are often subject to the biasing intrusions of real world beliefs, knowledge, values, and desires, which reflect a challenge in exercising the regulation necessary to ensure that hypothetical thinking is objective and systematic. Although, the regulatory skills improve over age and education, even college students are challenged by the regulatory demands of hypothetical thinking.

5. Dual Process Theory and Hypothetical Thinking: Theory and Applications

The same regulatory demands are echoed in the reviews of children's, adolescents', and adults' difficulties in reasoning about alternative possible worlds. The failure of children to critically reflect on alternative worlds was identified as the challenge limiting their ability to distinguish impossible from improbable events, to reason counterfactually, and to experience

regret. Although adolescents and adults could reflect on alternative possible worlds, they had difficulties regulating the intrusion of real world beliefs, knowledge, values, and desires into the process of creating, evaluating, and interpreting reality in light of possibilities. As a result, they had difficulty objectively and systematically anticipating and regulating regret and entertaining and evaluating causal hypotheses. The developmental trajectories for performance on all these tasks are different, but each has a common metacognitive challenge underlying the ability to objectively and systematically reason hypothetically.

In the present section, a dual process account of the hypothetical thinking is presented which proposes that the same metacognitive challenge underlies the ability to objectively and systematically think hypothetically. The metacognitive challenge involves consciously regulating cognitive processes so that a variety of hypothetical thinking skills can be coordinated in the service of interpreting the real world in light of alternative possible worlds. It is argued that the development of such metacognitive skills emerges in adolescence.

Dual Process theory proposes the existence of two parallel cognitive systems: Experiential and analytic. Experiential processing is regarded as the default processing system, responses from which are automatically activated and readily available. Such processing relies on concrete and contextualized task representations, rich in content from the situation, prior knowledge, beliefs, experiences, emotional reactions, and/or associations, often resulting in heuristic responding (Evans, 2006, 2007; Stanovich & West, 2000). Analytic processing is more conscious, effortful, and slower, often requiring the inhibition of experiential-based responses prior to the expression of analytic ones. Analytic processing may involve constructing decontextualized task representations, which require knowledge and skills that are acquired in

culturally specific contexts (e.g., schools), and resulting in responses that are normatively justified by formal logic or mathematics (Evans, 2006, 2007; Stanovich &West, 2000).

Evans (2006, 2007) provides a Dual Process account of hypothetical thinking on hypothesis testing situations, including the theory-evidence coordination tasks reviewed here. One such assumption is that causal hypotheses are processed analytically as *epistemic* mental models, which encode people's degree of belief, confidence, or uncertainty. So although processed differently than one's beliefs and knowledge regarding a particular variable, hypotheses are not held as epistemically neutral propositions (variable X is assumed to be neither causal nor non-causal) but as ones with epistemic status (e.g., variable X is assumed to have a low likelihood of being causal). Children who provide belief-based responses are likely not even engaging in analytic processing of variables as hypotheses, relying instead on experiential processing of their beliefs and knowledge that are automatically activated in the context. This does not mean that children do not revise beliefs in light of evidence, only that they do not consciously and effortfully reflect on the variables as hypotheses.

Adolescents, adults, and college students readily engage in the analytic processing of variables as hypotheses in hypothesis testing contexts, as reflected by their rate of evidence-based responses. Nonetheless, they may still be influenced by the epistemic values associated with different hypotheses. As a given hypothesis is further assumed to be evaluated singularly and relative to its epistemic value (Evans, 2006, 2007), a causal hypothesis will be retained until evidence clearly requires its rejection. As a result, variables believed to be causal and non-causal may well be evaluated differently despite the presentation of the same evidence. From this perspective, adolescents, adults, and college students are not *motivated* to seek out confirming evidence, but rather they are consistent in testing hypotheses for which they have different

degrees of credulity. Perhaps differences in evaluation for different hypotheses given the same evidence would disappear if participants were trained to adopt a general intellectual value that identical evidence must be interpreted identically for the different variables. Such may have been the case with advanced graduate students in Kuhn et al. (1988), who performed without bias on the theory-evidence coordination task.

The central assumption of Evan's (2006, 2007) Dual Process theory of hypothesis testing is the notion that to entertain and test hypotheses, default and automatic experiential processes must be inhibited in favor of conscious and effortful analytical processing. This regulation of the cognitive system to permit analytic processing of alternative possible worlds seems to be implicated in all other tasks considered in this review: modal reasoning, reasoning logically about possible (not pretend) worlds, counterfactual reasoning, and the regulation of regret. Children appear to have general difficulty doing this except in relatively restrictive contexts and with a good deal of support. However, adolescents and adults appear to do so spontaneously, but they may not always regulate their experientially-based belief, knowledge, and desires carefully enough so they do not influence analytic reasoning processes.

In a recent line of research I have been exploring the development of metacognitive skills to regulate dual cognitive processes (Amsel, Close, Sadler, & Klaczynski, 2009; Amsel, Klaczynski, Johnston, Bench, Close, Sadler, & Walker, 2008). The dual analytic and experiential processing systems need to be regulated so that the response associated with the more appropriate processing system would be expressed in the appropriate context. For example, probability judgments are made every day, and in many contexts a quick, experientially-based heuristic estimate of the probability of events is sufficient to achieve a goal or complete a task. At other times, probability judgments require more serious and analytically-

based reflective, thoughtful, and mathematically sound analysis of the situation. Metacognitive skills are required to permit default experiential-based responses to take precedence in the former case and analytical-based responses in the latter case.

In a total of five studies involving over 1,200 participants, we found that most preadolescents had notably poor metacognitive skills, failing to fully distinguish between analytical- and experiential-based responses. With age and education, most participants demonstrated a competent metacognitive status and correctly distinguished analytical- and experiential-based responses. Participants' metacognitive status predicted their performance on the ratio-bias task, in which they were presented with two equal gambles (e.g., 1/10 vs. 10/100). Participants were told that the gambles were equivalent and asked if they had *no preference* between the gambles or a preference for one gamble or the other. A large majority of participants with a poor metacognitive status had a preference for one or the other gamble (typically the one with more absolute winners, 10/100) and some were even willing to pay for the preferred gamble. Most (although not all) participants with competent metacognitive status gave *no preference* responses, were almost never willing to pay for a preferred gamble, and actually gambled less than others. One notable finding (Amsel et al., 2008, Study 1) was that performance on the ratio bias task was better predicted by metacognitive status, which indexes regulatory ability, than by Mathematics ACT scores, which index analytic mathematical ability.

These findings identify the development of competencies to regulate dual analytic and experiential processes, deemed necessary for objective and systematic hypothetical thinking. Amsel et al. (2008, Study 3) point to the importance of metacognitive status for hypothetical thinking. Participants were asked to complete the same ratio-bias task and were randomly assigned to do so from their own perspective or that of a logical person. According to dual

process theory of hypothetical thinking, the perspective instructions should elicit analytic processing to represent oneself *as if* one were a logical person, which should also result in more analytically-based *no preference* responses on the ratio-bias task. That was exactly what happened. The data suggested that the manipulation improved the analytic processing and did so particularly for those who had some competence to distinguish between the dual processes.

Similar hypothetical thinking effects of improving reasoning on other tasks were realized by inviting participants to adopt the perspective of others. Using the insight from dual process theory, I explored whether Introductory Psychology students would score higher on a questionnaire assessing scientific beliefs about psychology when they were invited to think like their psychology professors than they normally do (Amsel, Johnston, Alvarado, Kettering, Rankin, & Ward, 2009). We found that when Introductory Psychology students adopted the perspective of their Psychology professor, they affirmed the scientific basis of the discipline more strongly than they normally do, and affirmed those beliefs as strongly as senior psychology majors (Amsel, Baird, & Ashley, in press). Performance on simple physics problems also improved when physics students were invited to think like their physics professors rather than as they normally do (Amsel & Johnston, 2008). Inviting students to engage in hypothetical thinking about their professor's perspective on a discipline appears to help them think more analytically about the discipline and its assumptions. Future research is exploring the development of such hypothetical reasoning effects across a variety of different disciplines that make up the general educational curriculum of many universities (English, History, and Human Development).

6. Summary and Conclusions

The precise emergence of hypothetical thinking is difficult to precisely pinpoint. However, it is reasonable to identify adolescence as the approximate time of emergence of

hypothetical thinking for three reasons. First, there is a convergence of evidence from a range of tasks that specifically require reasoning about possible worlds that the ability to do so develops in later childhood or early adolescence. These tasks include treating alternative event sequences as possibilities, logically inferring consequences from possible worlds, counterfactual reasoning, experiencing or anticipating regret, and modal reasoning. Second, these tasks have in common a set of skills typically thought to be related to general cognitive and metacognitive development during adolescence (Kuhn, 2009). These skills include critical reflection (on possible worlds), systematic inferences (about those worlds), and objective interpretations (of reality in light of them). Third, there are critical metacognitive skills acquired during adolescence to regulate the dual processes and specifically to distinguish experiential and analytic processes (Amsel et al., 2008, 2009). Such skills are central to thinking analytically about possible worlds in the form of epistemic mental models and interpreting reality in light of them.

Armed with these general cognitive and metacognitive and specific hypothetical thinking skills, adolescents can interpret reality in light of possibilities, thereby achieving what Inhelder and Piaget (1958) proposed to be uniquely acquired by and transformative for adolescents: Subordinating reality to possibilities. However, there remain many cases where adolescents and adults fail to reason hypothetically in an objective and systematic manner because of the influence of prior beliefs, knowledge, and desires. This was exemplified in hypothesis testing research. However, such cases of bias were not motivated but can be traced to the inevitable consequence of analytically processing possible worlds as epistemic mental models. People may hold different epistemic values for the same possible worlds, and so may make different inferences about them and differently interpret reality in light of them. Even still there remains the influence of experiential processes in analytic ones on a variety of hypothetical thinking

tasks. Perhaps skills to reason hypothetically are subject to expertise effects. Adolescents may be novices at hypothetical thinking and become more objective and systematic in their hypothetical thinking through feedback and practice. For example, perhaps the negative consequences of experiencing *unanticipated* regret may make adolescents more motivated to think hypothetically and make decisions that anticipate and avoid regret.

Although the proposed model of hypothetical thinking is consistent with Piaget claim about *when* hypothetical thinking is acquired, it is not consistent with *how* it is acquired. From the dual processing framework, hypothetical thinking is acquired in adolescence due to their development of general cognitive and metacognitive and specific hypothetical thinking skills but not the acquisition of formal logico-mathematical structures. Rather than holding that the development of hypothetical thinking is a by-product of formal logical ability indexed by combinatorial reasoning, the evidence suggests that it is a by-product of coordinating specific hypothetical reasoning skills to critically reflect on possible worlds and the metacognitive and regulatory skills to create, make inferences about, and interpret reality in light of possible worlds.

There is an ironic quip that goes, "Imagine a world without hypothetical thinking." It is hard to imagine such a world as the ability to think hypothetically is ubiquitous, representing some of the most fundamental and uniquely human forms of thinking. In an important way, the acquisition of hypothetical thinking makes adolescents adult-like. Although novices at it, hypothetical thinking is a transformative ability, enabling adolescents to understand reality in light of possibilities. There are documented ways in which hypothetical thinking, and the regulation of analytic and experiential processes it entails, affects the quality of judgments, reasoning, emotions, decision making, and learning. To perfect these skills adolescents need practice in thinking hypothetically, which seems to be something they readily do.

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Figure 1: Percentage of consistently correct participants by Instruction Condition and Age Group in Amsel, Trionfi, and Campbell (2005), Study 2.

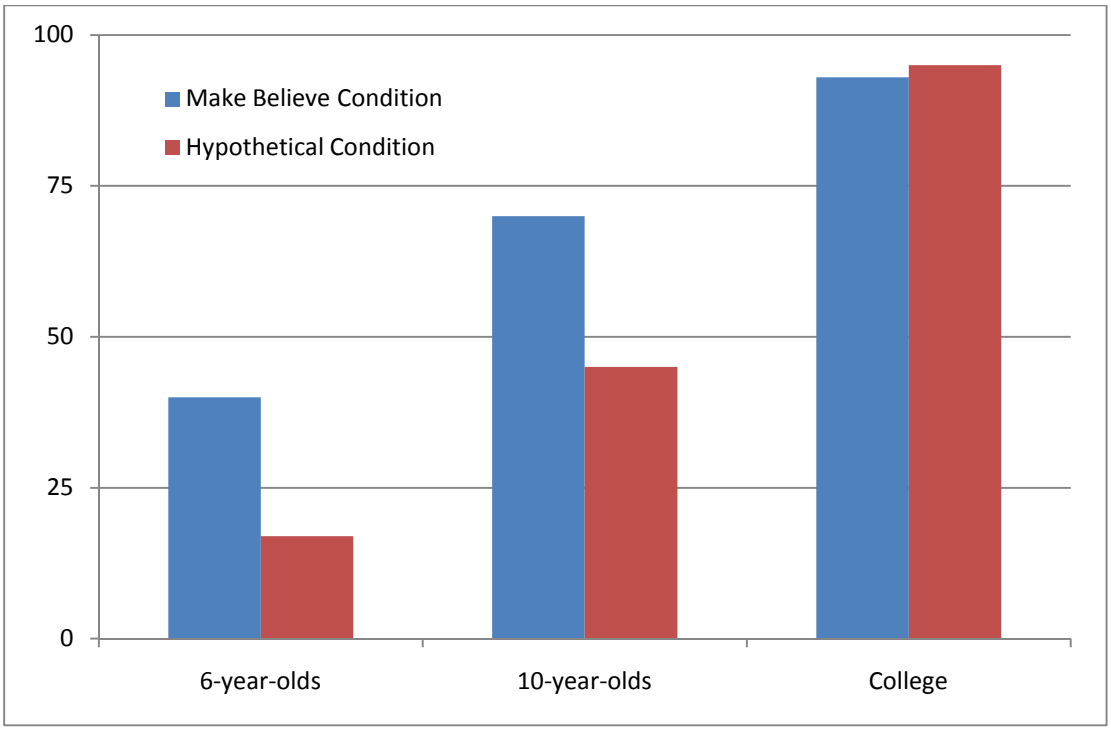
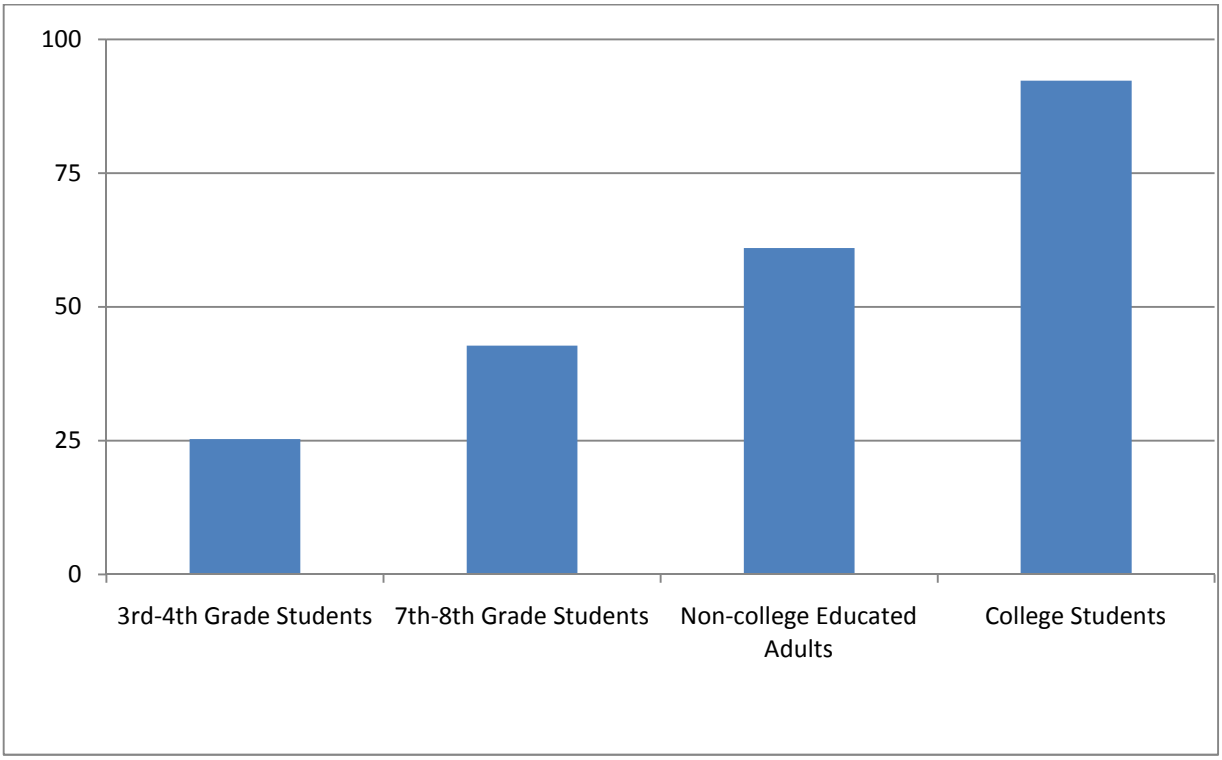
Figure 2: Percentage of evidence-based responses by Age Group in Amsel and Brock (1996).