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An analysis of current evidence supporting two alternate learning models: learning styles and dual coding

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Abstract

This paper examines the research evidence behind two alternate and mutually exclusive learning models- learning styles and dual coding. The most common incarnation of each model is based on learning modalities, and each makes predictions about how learners process auditory and visual stimuli. Learning styles have found wide acceptance in public perception and throughout education at all levels, yet the majority of empirical research suggests that the model is not accurate and that learning styles instruction has no effect on student learning. Dual coding is more strongly supported by empirical research yet less well known and less commonly used in practice. The analysis examines evidence from a wide variety of sources, including experimental studies, correlational research, teacher-education texts, and neuroimaging studies. The findings reveal that dual coding is likely to be the more accurate model and that it offers more potential for both research and in practical application.

Keywords: learning styles; dual coding; cognition; visual; auditory; interaction effect; retention

1. Two conflicting models

In recent years learning theory and educational practices have increasingly focused on the use of various learning modalities to deliver instruction and, ostensibly, improve learning and retention. Perhaps the most prevalent model is the learning styles hypothesis, which has become widely accepted by the general public and educators at all levels (Pashler, McDaniel, Rohrer, & Bjork, 2009), including in teacher education and adult education programs (Bishka, 2010), as well as being promoted in k-12 schools in many countries (Scott, 2010). However, acceptance of the learning styles hypothesis has far outpaced the research evidence that supports it, as you will see below. The basic premise of the learning styles hypothesis is that if an instructor matches the mode of instruction to the learner's preferred mode of processing, then learning is promoted. So, for instance, if a visual learner is presented information visually, then learning should increase, according to the hypothesis. Likewise, if an auditory learner encounters information delivered in an auditory fashion, then learning should be enhanced. This is known as the matching hypothesis, and it is the foundation for the learning styles instructional model. While there are a variety of learning styles frameworks in use, the practice is most likely to take the form of delivering instruction in visual, auditory, kinesthetic, and read/write modes to match students' visual, auditory, kinesthetic, or read/write learning preferences, otherwise known as the VAK or VARK model largely developed by Fleming and Mills (1992).

Dual coding is an alternate and less well known theory that suggests that there are two independent pathways for encoding information into long term memory, one visual and one verbal (Di Virgilio & Clarke, 1997; Hodes, 1998; Paivio, Walsh, & Bons, 1994; Sadoski, Goetz, & Avila, 1995; Shen, 2010; Welcome, Paivio, McRae, &

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Joanisse, 2011). Because almost all human learning involves language processing to some degree, dual coding predicts that retention should increase if visual stimuli or imagery are incorporated in addition to linguistic processing. The visuals and imagery would produce an additive effect and essentially create another storage mechanism for long term memory, going beyond linguistic processing, and allow the learner to avoid cognitive overload from too much verbal information being processed simultaneously. And, as you will see, while attention to dual coding does not approach the ubiquitous scope of learning styles instruction in practice or in public perception, there is a great deal more research evidence to support it.

In examining the evidence for these two concepts, it is important to understand that they are mutually exclusive. They cannot both be accurate models of human cognition. One, learning styles, predicts that learning is enhanced when instruction is matched to the learner's preferred modality, so that auditory learners should retain the most information under auditory conditions and kinesthetic learners should retain the most under kinesthetic conditions. In contrast, dual coding predicts that all learners, regardless of their preferred modality, will learn most efficiently when they encounter visual information layered upon the omnipresent linguistic stimuli. This would contradict the most basic foundation of the learning styles hypothesis because it suggests that learners who report preferences for auditory or kinesthetic instruction would actually thrive the most in response to visual instruction, instruction that would be in contrast to their learning preferences. Therefore it is important to analyze the existing research on both concepts to ascertain which model is an accurate representation of human cognition and which of the two should be adjusted or discarded.

2. Learning styles and the matching hypothesis

2.1. A brief history of aptitude-treatment interaction effects

The phrase *learning styles* refers to the concept that different people prefer to process information in different ways and therefore learn more effectively when they receive instruction in a way that conforms to their preferences (Pashler, et al., 2009). A modality is the sensory form through which the information is processed, i.e. visual, auditory, etc., and a learning style is believed to be the preferred modality of the individual learner. Thus, if instruction is designed so that a student is required to learn by viewing a chart, then that instruction is centered around a visual modality, and if the student has a preference for visual learning, then that instruction would be said to match the student's learning style. The inventories created to measure learning style preferences generally classify learners into different style categories. Since at least the 1960s researchers have hypothesized about aptitude-treatment interaction (ATI) effects, the idea that a learner's aptitude, in some cases characterized by a preference such as learning style, can interact with a corresponding treatment to produce an enhanced effect, most commonly purported to be increased learning (Scott, 2010). By the 1970s the bulk of the empirical research on the subject had refuted the most common hypotheses associated with ATIs, yet the idea reemerged a decade later to find unprecedented acceptance and widespread use in the form of learning styles-based instruction. These practices are so widely accepted that they go largely unquestioned (Bishka, 2010). The vast amount of educational time, resources, and funds spent on learning styles would suggest that a close examination of the claims behind the practice and the supporting research is warranted.

A number of researchers trace the learning styles phenomenon to Gardner's (1991; 1993) concept of multiple intelligences (Allcock & Hulme, 2010; Fridley & Fridley, 2010). Gardner initially proposed that there are eight forms of intelligence that all people possess: visual-spatial, verbal-linguistic, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, musical, and naturalistic. Allcock and Hulme (2010) argue that Gardner's multiple intelligence theory has influenced the learning styles approach by advocating matching instruction to students' preferred learning style. They point out that many teachers are expected to consider all intelligences

when lesson planning in order to appeal to students' learning styles. Fridley and Fridley (2010) also link the expansion of learning styles to Gardner's hypothesis and emphasize inherent weaknesses in Gardner's model. Gardner's propositions have encountered substantial criticism in the field of psychology due to a lack of empirical support, yet the concept of learning styles has spread rapidly throughout all levels of education nonetheless.

2.2. Recent evidence and doubts concerning the learning styles hypothesis

In 2009 a team of highly regarded cognitive psychologists (Pashler, et al., 2009) published an influential paper in which they identified the type of evidence necessary to validate the learning styles hypothesis and then sifted through the literature in search of studies that could provide that sort of evidence. In order to confirm the matching hypothesis, which asserts that learning will flourish when the modality of delivery is matched to the learner's preference, an experimental design must be employed and results must show a significant interaction effect in each condition. This means that a statistical analysis should reveal that someone identified as a visual learner learned more when presented with visual information, while an auditory learner thrived in response to auditory information, and so on for each condition and each learner preference.

What Pashler et al. (2009) found was that there was virtually no research at all that could provide this sort of evidence for the existence of learning styles or their impact on student learning. Instead the literature was comprised of doctrinaire papers lacking empirical data that would qualify as little more than essays and correlational studies that could not identify causation and simply assumed that a reported preference would have an impact on learning. Since then a wave of other researchers have examined the literature and similarly noted the lack of evidence for the model (Bishka, 2010; Fridley & Fridley, 2010; Mayer, 2011; Norman, 2009; Riener & Willingham, 2010; Rohrer & Pashler, 2012; Scott, 2010). Yet this surge of peer-reviewed articles questioning the validity of learning styles has had a limited impact on popular perception.

There are studies that appear, on the surface, to support the use of learning styles, but the vast majority of the published research claiming positive findings for learning styles has been comprised of descriptive and correlational studies that did not have the ability to test the matching hypothesis, identify interaction effects, or show causation (Al BuAli, Balaha, & Al Muhaidab, 2013; Aliakbari & Qasemi, 2012; Amran, Bahry, Yusop, & Abdullah, 2010; Anu & Anuradha, 2012; Breckler, Teoh, & Role 2011; Crawford, Alhreish, & Popovich, 2012; Gholami & Bagheri, 2013; Katsioloudis & Fantz, 2012; Muscat & Mollicone, 2012; Ozgen & Alkan, 2012; Tumkaya, 2012; Vahid Baghban, 2012; Weng, 2012; Yenice, 2012; Yilmaz & Genc, 2010). None of these studies purporting to have found support for learning styles actually used a design or analysis that was capable of providing evidence for the model's efficacy. Many other studies showing favorable results for the learning styles hypothesis were published in predatory, pay-to-publish journals with highly questionable publishing standards and therefore will not be cited here.

The most rigorous empirical studies published on the topic since 2009 have shown a consistent trend. They found no effect of learning styles or the matching hypothesis (Allcock & Hulme, 2010; Choi, Lee, & Kang, 2009; Kappe, Boekholt, den Rooyen, & Van der Flier, 2009; Kozub, 2010; Sankey, Birch, & Gardiner, 2011; Zacharis, 2011). These studies did use some form of experimental design and tested the matching hypothesis yet did not find evidence for it. Martin (2010) conducted a factor analysis on two commonly used learning styles inventories and found they lacked validity to such an extent that the results provided teachers with information that was essentially random, thereby negating the teachers' ability to match instruction to any student's preferences. Two experimental studies did find an interaction effect, but one of those tested a variety of different behavioral outcomes rather than learning (Mahdjoubi & Akplotsyi, 2012), and the other used such a small sample size (N=39) and limited intervention (Hsieh, Jang, Hwang, & Chen, 2011) that the results would need to be

replicated to enhance their credibility, particularly in light of so many other contradictory findings.

2.3. Learning styles in Teacher Training

The bulk of the current empirical research evidence suggests that the learning styles hypothesis is not accurate, yet uninformed acceptance of the practice reaches beyond the general public and into teacher education programs where it promulgates in an official capacity under the auspices of best practices in college courses. Teaching candidates are exposed to the claim that learning styles not only exist but also impact learning and are encouraged to use the practice in k-12 classrooms. A recent review of common general teacher education texts (Cuevas, 2015) revealed that they all included sections on learning styles and they all advocated for instruction to be based on them (Carjuzaa & Kellough, 2013; Hipsky, 2011; Powell, 2012; Silver, Strong, & Perini, 2000; Smith & Throne, 2009; Tomlinson, 2001; Wormeli, 2007). None of these texts mentioned a lack of support in the research literature, cited any empirical studies that could substantiate the model, or hinted that there were questions about the validity of learning styles. Instead, they tended to present the information as if the learning styles hypothesis had been confirmed and encouraged teaching candidates to use the practice in the classroom.

In contrast, educational psychology texts designed for teacher education programs tended to be more measured in their discussion of learning styles. Each one pointed out the scarcity of supporting research on learning styles or the related hypothesis of multiple intelligences (Bohlin, Durwin, & Reese-Weber, 2012; Eggen & Kauchak, 2013; Henson & Eller, 2012; Kauchak & Eggen, 2011; Ormond, 2012; Santrock, 2011; Slavin, 2012; Woolfolk, 2013). These texts tended to note the controversy surrounding instructional practices based on aptitude-treatment interaction effects and cautioned readers to be skeptical of methods that are not supported by research. So there is a substantial difference between the way the issue is treated in general education texts and educational psychology texts, with general education texts advocating for learning styles instruction while failing to cite any empirical support or to provide critical analysis, and educational psychology texts representing the issue in a way that was more congruent with current research findings.

Ultimately, while no one denies that there are cognitive and personality differences in individuals, the current evidence casts serious doubt on both the existence of learning styles and, if they do exist, their ability to influence learning. Yet the practice continues to be widely accepted and is propagated through teacher-education programs and the texts that are commonly used to inform teaching candidates. A deeper look into research on human cognition is necessary to evaluate the validity of the assumptions of the learning styles hypothesis.

3. Dual coding

An alternative theory, dual coding, is more strongly supported by experimental research but somewhat paradoxically less well known and less likely to be intentionally employed in a learning environment. While we are still unsure of the exact mechanisms that govern dual coding, the basic premise is that there are two separate pathways for encoding information into memory, one verbal and one visual, and that the two systems are interconnected physiologically within the cerebral cortex, yet functionally independent (Di Virgilio & Clarke, 1997; Fiebach & Friederici, 2003; Hodes, 1998; Welcome, Paivio, McRae, Joanisse, 2011). Decades of research have fairly well established that the incorporation of mental images and visual representations are associated with higher levels of recall than verbal items (Hodes, 1998; Sharps & Price, 1992), which would seem to contradict the learning styles hypothesis that suggests that auditory and kinesthetic learners should show better retention with corresponding modes of instruction.

3.1. Hemispheric views of dual coding

Conceptual knowledge is widely distributed among neural networks throughout the brain, yet pathways connecting those networks appear to be distinct, particularly in regard to auditory and visual stimuli (Patterson, Nestor & Rogers, 2007). Researchers have traditionally used behavioral, patient, ERP, and neuroimaging studies to explain these visual and auditory distinctions in terms of the differentiated tasks that the two cerebral hemispheres are responsible for (Fiebach & Friederici, 2003; Funnell, Corballis, & Gazzaniga, 2001; Jessen et al., 2000). From this perspective dual coding can be indirectly traced to split-brain surgeries performed in the 1940s to sever the corpus callosum, the part of the brain that connects the two cerebral hemispheres, in patients who experienced life threatening seizures (Gazzaniga, 2005). Once the hemispheres were split it allowed scientists to examine the function of each one in isolation, which produced a wealth of information on lateralization. What we know now, with a high degree of certainty and from many different lines of research, is that the left hemisphere is responsible for most language function while the right is responsible for most spatial reasoning and visuospatial processing.

Nearly everything we learn is processed via language through our left hemisphere, including almost all academic information. Until we can name a concept or explain how it relates to other concepts, it is virtually impossible to form any durable representation of it. Even in areas such as geometry with its heavy reliance on spatial reasoning and science with its incorporation of hands-on labs, it is still essential that learners encode terminology at each step of the process in order to allow for long term retention and new learning. But our brains are limited and prone to cognitive overload which causes us to dump information, particularly linguistic information, if too much of it is fed into working memory, our "here-and-now" focus of attention.

The traditional bihemispheric view of dual coding predicts that there are parallel pathways for retaining information- one for language on the left side and another for visuo-spatial information predominantly processed on the right side- and if the visuo-spatial centers on the right are activated during the process then the combined computational power of bringing both hemispheres into use will increase our ability to retain information (Funnell, Corballis & Gazzaniga, 2001; Gazzaniga, 2005). And pictorial information requires integration between the two hemispheres (Funnell, Corballis & Gazzaniga, 2001). Hence, imagery can serve to compensate for the limitations of working memory by adding a supplemental information store that does not produce cognitive overload in the linguistic centers (Hodes, 1998). And when imagery and language are used in conjunction, it has been shown that less activation of language centers occurs than when language is the only source of information (Mazoyer, Tzourio-Mazoyer, Mazard, Denis, & Mellet, 2002). This would suggest a shared load and provide an explanation for why the extra information is associated with greater retention but not cognitive overload.

3.2. Research using concrete vs abstract words

The majority of studies on dual coding have contrasted retention of abstract words to retention of concrete words (Jessen et al., 2000; Mazoyer et al. 2002; Paivio, Walsh & Bons, 1994; Sadoski, Goetz & Avila, 1995; Welcome, et al., 2011). The rationale for this is that abstract terms like "justice" or "love" are not easily linked to visual imagery and should be processed almost solely in the language centers in the left hemisphere. Conversely, concrete words such as "hammer" or "building" are associated with visual concepts, and imagery is often employed when encoding or retrieving them. The individual essentially "sees" images during encoding and retrieval of concrete words. Bauch and Otten (2011) recently found that information that is strictly conceptual (i.e. a word with no perceptual value) is less likely to be retained than words that have perceptual traits and can be imaged.

While it is true that visual information is handled by both hemispheres, our spatial perceptions are normally entirely dependent upon vision. There are very rare instances of blind individuals who use echolocation to create spatial awareness, and you might

use your hands to navigate in the dark when the power goes out at night, but these tend to be extreme exceptions. For most of us spatial reasoning is dependent upon vision, and therefore concrete words that elicit images may produce more activity in the right hemisphere where spatial awareness and vision intersect and important temporal judgments are made about visually presented stimuli (Funnell, Corballis & Gazzaniga, 2001). In a study of a callosotomy patient whose corpus callosum had been severed, Funnell, Corballis, and Gazzinga (2001) found that memory performance with pictures was superior when they were presented to the right hemisphere, leading the researchers to conclude that memory traces are lateralized to some degree. The patient's memory was best when he was presented with namable objects that would incorporate both the left hemisphere by stimulating language function and the right by stimulating visual images. Additionally, the use of imagery has been shown to have much the same effect as seeing the actual images (Sharps, Price & Bence, 1996) so it is possible that identical pathways are used when processing both visual images and stimuli that elicit imagery.

Of the studies that have tested dual coding using neuroimaging, a number have found that indeed more activity appeared in the visuo-spatial regions in the right hemisphere when participants processed concrete words. Jessen et al., (2000) used fMRI to determine that the lower right parietal lobe showed significantly stronger activation when participants thought about concrete words. However, the areas that were activated were associated not with visual imagery but with spatial imagery, causing the researchers to conclude that the participants were perceiving the images in 3-dimensional space rather visualizing them in a 2-dimensional photo-like image.

Mazoyer et al. (2002) found that participants' recall of concrete words was superior to that of abstract words, and PET analysis showed activation in visual regions when participants processed those concrete words. This supports dual coding theory in that the extra visual dimension associated with concrete words improved recall, as opposed to limiting it due to excess information leading to cognitive overload. Similarly, Welcome et al. (2011) used EEG and found a main effect of concreteness. When participants engaged in either imagery tasks or linguistic tasks, the spatial and language centers showed different patterns depending on the type of stimuli. These studies generally showed that participants had greater retention of the words that required the incorporation of both hemispheres.

3.3. Conflicting findings regarding the traditional model for dual coding

Other studies, however, have raised doubts about whether dual coding is related to the divergent responsibilities of the two hemispheres. Using fMRI, Fiebach and Friederici (2003) found that when participants processed concrete words there was increased activation in the basal regions of the left temporal lobe in contrast to abstract words, yet when abstract words were processed there was greater activity in the left inferior frontal areas. The left basal temporal cortex, where concrete terms produced greater activation, is involved with visual processing and image formation. While these findings do not support the traditional bihemispheric assumptions since the differences were found to occur in the left hemisphere rather than the right, they do support the broader premise of dual coding that predicts different pathways for coding, one of which incorporates additive visual/imagery processing. Shen (2010) used cognitive testing to come to a similar conclusion and argued that both hemispheres are involved in all visual and linguistic encoding, but that the information from each is processed in different ways.

While some evidence has identified the neural systems in the left temporal lobe to be important for retrieving concrete words, particularly in the left inferotemporal (IT) regions, one study used PET and found that activation in the left IT region was the same for both abstract and concrete words (Tranel, Grabowski, Lyon, & Damasion, 2005). This led the researchers to conclude that the left IT region might be a hub where both visual and linguistic information is processed but that visual and linguistic pathways may diverge in other areas. Others have also argued that evidence points to a distributed-plus-hub model where information from various areas is sent to a central

hub and redistributed, instead of a distributed-only model in which certain areas communicate only with certain other related areas via direct neuroanatomical pathways between sensory, motor, and linguistic regions (Patterson, Nestor & Rogers, 2007). If this is the case, it would contradict the traditional bihemispheric model and suggest a more complex explanation for differences in encoding verbal and visual stimuli.

Still others (Cowan & Morey, 2007; Morey & Cowan, 2004) have argued that there may actually be only a single storage component to memory rather than dual pathways, therefore calling the basic premise of dual coding into doubt. Cowan and Morey (2006) have suggested that instead of individuals having modality-specific memory faculties, with visual and auditory information being stored separately and automatically, there may be a central storage mechanism for both, and that the quality of encoding is based more on attentional processes. In an experiment designed to test this assumption they found that inaccurate recall of verbal prompts was associated with inaccurate recall of visual prompts leading them to infer that memory in both domains is dependent on a central resource rather than two independent ones (Morey & Cowen, 2004). It is unclear whether the authors would view this central resource as the aforementioned hub with the possibility of other pathways for the various modalities or if they believe the existence of a hub would negate the possibility of dual coding.

Context availability theory is an alternate explanation for the effects that have been documented for dual coding, and it found some favor in the 1980s (Schwanenflugel & Shoben, 1983). Context availability theory suggested that concrete terms are associated with broader contextual support in terms of existing schemata, and this is what accounts for superior memory performance with those terms (Jessen et al., 2000). Essentially, we relate concrete terms to a wider variety of other concepts than we do abstract terms, and because of this, concrete terms are more readily encoded and retrieved. However, several studies since that time have tested context availability theory against a dual coding model and found dual coding to be a better explanation for the results of those experiments (Fiebach & Friederici, 2003; Paivio, Walsh & Bons, 1994; Sadoski, Goetz & Avila, 1995). While Jessen et al. (2000) could not rule out context availability theory, they did find evidence for dual coding, suggesting that if context availability plays a role, it does not supersede dual coding. Thus, context availability theory is no longer considered to be a more valid interpretation than dual coding for explaining differences in how concrete and abstract terms are coded, and because it is considered a framework for verbal information only, it could not account for the way in which purely visual stimuli is processed.

Ultimately, there is a substantial amount of research evidence that indicates that we encode visual and auditory stimuli differently and that when visual information is paired with and layered upon linguistic information retention is superior to when linguistic information is the sole source of input. While many researchers have argued that this is due to hemispheric differences in the cerebral cortex and that the benefits of dual coding are the result of activating both the left and right hemispheres simultaneously in the process, the facts regarding the neurological mechanisms involved are far from settled. There are several possibilities to explain how brain physiology contributes to the findings that have been documented. Neuroimaging has advanced to the extent that we may have answers to these questions on the near horizon. What seems to be less disputable is that visual information differs from auditory information in the way that it is processed and the outcome of this differential processing can be measured in terms of memory representation. This has implications for our understanding of learning styles and for practices used for instruction.

4. Conclusions

4.1. Future research

Additional research on both learning styles and dual coding is warranted, though for different reasons. While the bulk of research and the most rigorous studies on learning styles suggest that it is neither an accurate model for how humans learn best nor an effective instructional strategy, it remains widely popular in public perception and in practice, from k-12 through college. It is possible that we may find that learning styles do have an impact on behaviors or choice of vocational tracks, but at this point the evidence suggests that they do not influence academic learning. However, because of the widespread use of learning styles instruction in schools and the broad misconceptions about its effectiveness, additional published research is likely one of the few avenues available to clarify the public record on the topic and rectify what has become one of the most common myths in education (Kirschner & van Merriënboer, 2013).

In contrast, dual coding offers a promising area not only for future research but also for practical application. There is good reason to conclude that learners will benefit from being presented with a mixture of visual and auditory information that will stimulate encoding through the two independent pathways for retention however they may be structured in the brain. While the capability to perform neuroimaging studies is available to only a small portion of researchers, experiments that focus on cognition and behavior are a viable option for most researchers in the fields of education and psychology, and these types of studies could shed further light on what we currently know about dual coding. For instance, while the vast majority of research on the subject has tested retention of concrete words in contrast to abstract words, one possible course would be to present learners only with concrete words but prompt them to encode the information via either auditory or visual means. This would address any lingering questions posed by context availability theory since a concrete word should elicit the same contextual connections regardless of the modality of delivery. If, however, retention was equivalent under both conditions it could provide reason to reexamine context availability theory and may cast some doubt on the concept of dual coding via two separate pathways.

Because the learning styles hypothesis and dual coding theory are mutually exclusive models of cognition, an important line of research would be to test them against one another in a single experiment. Students' learning styles would first be assessed using one of the common VAK survey instruments. Then content could be delivered to different groups through visual and auditory methods, and possibly incorporate kinesthetic and read/write conditions as well. If, upon assessment, a significant interaction effect was found for each condition and students showed the greatest retention when the instructional condition matched their learning style, the study would be one of the first to provide results of that nature in favor of learning styles. It would also be a first step in disproving dual coding theory because if an interaction effect were to be found it would indicate that a preference for auditory or kinesthetic learning outweighed any additive benefit provided by a potential visual pathway for processing information. Conversely, if no interaction effect was found and instead students in the visual condition consistently retained more information than those in the other conditions, it would provide further evidence that learning styles instruction is not effective. If, in this case, students thrived when visual information was layered upon linguistic information regardless of their learning style preference, then that finding would be consistent with dual coding theory while refuting the most basic premise of the learning styles hypothesis. To date there are no studies that have directly tested this.

4.2. Implications

The vast amount of time and financial support that are allocated to education would seem to necessitate additional research in these areas, particularly when one considers

how finite these resources are. If, as most research currently suggests, the learning styles instructional model is not an effective one, then the enormous amount of instructional time and funds that are currently devoted to it must be viewed not just as a net loss, but as a highly detrimental development in education. These valuable resources could be directed towards practices that we have stronger reason to believe will be effective. During a time when the efficiency and effectiveness of instruction have become prominent issues that reach beyond education and into political discourse, the need to examine the validity of models such as the learning styles hypothesis should be at the forefront of educational research.

And if dual coding is found to be a more accurate model of human cognition, as most current research would suggest, there are possibilities for its use in the classroom. With the prevalence of technology that is available in classrooms from kindergarten through graduate schools, there are limitless options for instructors to pair visual prompts with each concept that they cover so that, if there are indeed dual pathways for encoding, students' retention of the material will be enhanced via the additive effects of images. And because technology has become ubiquitous in most formal academic environments, dual coding has the potential to offer benefits without the need for a great deal of additional monetary investment. For these reasons it may be prudent to begin a shift away from the learning styles model and towards more well supported ones such as dual coding even while further research is conducted to add to the existing body of evidence.

Based on the current status of research in the area, several recommendations for classroom instruction may be made. First, teachers should not allocate planning time or instructional time to attempting to match learning activities to students' learning styles. Research at this time simply does not support such practices as being effective learning strategies. But teachers could very well put the principles of dual coding into use, though the practical application of it may be subtle and unnoticeable to the untrained eye. For instance, teachers should avoid exposing students to stimuli that requires extensive reading while simultaneously lecturing or engaging in discussion. This is an all-too-common occurrence as teachers ask students to copy notes from the board or display PowerPoint presentations with elaborate written details while at the same time explaining the concepts to students orally and asking questions. Dual coding theory would suggest that this type of activity would throw students into cognitive overload by requiring them to process an overabundance of verbal information simultaneously, and in doing so would cause them to retain less of the information than they would otherwise.

Instead, teachers should always keep in mind the need to supplement information with visual stimuli and be cognizant of the benefits it may have to students' retention of material. Rather than creating PowerPoints and Prezis with paragraphs and extensive written explanations, the presentations should only contain key words or phrases for overarching themes and predominantly feature visuals that relate to the concepts being discussed verbally. These could include charts, graphs, pictures, drawings, videos, and any other visual cues that support the concept. Teachers could also create group activities in which students match written concepts to corresponding visual images. While these types of activities are currently in use in classrooms, it is likely that most teachers do not use them consistently or plan out instruction with the principles of dual coding in mind. It is more likely that visuals are used as a matter of convenience when a video or picture obviously relates to a certain concept being covered. But if, when teachers sit down to plan every lesson, they examine the academic language involved and make a concerted effort to find and pair images of some sort with that language, there is reason to believe it may enhance students' learning.

It is paramount that classroom practices begin to better align with the research we have compiled on human learning. Too often questionable strategies such as the learning styles approach have come to dominate education without credible evidence for their use, while more well-supported models such as dual coding languish in the pages of research studies that teachers are never exposed to. The term "research-based instruction" cannot continue to be little more than a rhetorical device to justify

practices that are not actually supported by research. If we expect to improve educational outcomes for students in the future we must be able to put aside ineffectual methods and embrace others that are substantiated by empirical evidence. By using what science has taught us about visual processing, it would be one small step in this direction.

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