Re-Examining the Mental Imagery Debate with Neuropsychological Data from the Clock Drawing Test

Anupam Guha
School of Computer Science,
Georgia Institute of Technology
aguha7@gatech.edu

Hyungsin Kim
School of Interactive Computing,
GVU Center
Georgia Institute of Technology
hyungsin@gatech.edu

Ellen Yi-Luen Do
School of Interactive Computing,
GVU Center, Health Systems Institute
Georgia Institute of Technology
ellendo@gatech.edu

Abstract

Reasoning by the usage of mental images has been the subject of much debate in Cognitive Science, especially among the schools of depictive and descriptive imagistic representations. Whether or not reasoning with mental images involves a mechanism or a process different from language based reasoning is an important question. This paper proposes that any theory which aims for a cohesive whole needs to be constrained by neurophysiological data and such data can be obtained by the Clock Drawing Test. The Clock Drawing Test (CDT) is a screening tool for cognitive impairment and can be used as a tool to test resilience of certain factors of visual spatial representations. Thus, it can help to form an empirical case for which factors are prone to debility and which factors are not during the onset and progress of cognitive impairment from a mental representation point of view. This paper presents 50 CDT tests done on patients with cognitive impairment and analyses the results which support the case for a depictive rather than a descriptive theory for imagistic representations. Lastly, this paper proposes that there is some evidence for a more dynamic and distributed nature of representation in the observations which question the above dichotomy and can be partly explained by certain aspects of the connectionist school of thought.

Introduction

Cognitive Science in general and the symbolic paradigm in particular has been wrestling with the question of mental imagery for a while and has found strong advocates on both sides of the debate, roughly described as the 'depictive' school and the 'descriptive' school. In particular we focus on the arguments of Kosslyn et al.(Kosslyn 1994) in support of the depictive theory of imagery and Pylyshyn as the primary opposition to it (Pylyshyn 2002) though of course there are more arguments to be considered on either side. The paper will start explaining the primary points of contention in said debate and then will propose that the Clock Drawing Test (CDT) can prove to be an important tool to gather evidence pertinent to re-examining the debate. The CDT is an easily administrable cognitive screening test which has proven useful in detection of Executive Dysfunction (Shulman 2000) which has a direct relationship with functional frontal pathology (Elliott 2003). That combined with the fact that the CDT primarily measures visual spatial reasoning processes makes it an ideal tool to measure which factors of visual reasoning are robust and which factors are prone to damage during cognitive impairment. The thesis of this paper states that factors which are 'weak' or prone to damage are the ones mainly dependent on high level cognitive control, which would be directly damaged by Executive Function Deficit (EFD) thus can give a better understanding of how the symbolic representations of images occur. Conversely, the factors which are 'strong' or resilient during cognitive impairment are the more fundamental low level representations, and help to reckon the nature of the symbols in said symbolic theory. Thus the hypothesis of the paper is that consistent observable patterns in visuo-spatial reasoning will be observed on application of CDT to a general set of patients with cognitive debility, and these results will be indicative of how visual representations may exist. This results from the fact that the CDT directly maps EFD to impairment in visual reasoning. The paper accepts that many of the observations generated might have alternate explanations than those provided, especially explanations of tacit knowledge or specialized cognitive machinery. Having said that, we posit that the observations of CDT are significant and are consistent enough to warrant an investigation with respect to the imagery debate.

A succinct description of the imagery debate

The 'Cartesian Theatre' view of the imagery (Dennett 1991) was matured and had its most developed theory developed by Kosslyn (Kosslyn 1994) and this school of thought has found widespread support among cognitive scientists. It was accepted in this theory that images do not preserve perceptual phenomena perfectly. It was also accepted that a priori knowledge plays a part in reasoning with images. However, this theory states, the real difference between this theory and its counterpart, namely that images are processed not much different than other forms of reasoning (by which it is meant language based reasoning) is that when imagery relies on a *fundamentally different representation* internally from language. This theory states, that at a functional level image are intrinsically spatial or geometric and that intrinsically, the distance properties of images are preserved in their representation (Kosslyn 1994).

There has been empirical findings in support of this theory (Shepard and Feng 1972 and Finke and Pinker 1982) as well as recent developments in neurobiology (fMRI primarily) which have lend support to the concept of topographically organized areas (Finke, Ward, and Smith 1992), primarily by findings which show compelling evidence of retinotopic organization of the human visual cortex (Van Essen et al. 2001).In some of these tests (Klein et al. 2000 is a very important study) direct relation was found between, say orienting an image vertically and then horizontally, and observing the fMRI results which show the pattern of activation on Area 17 (Brodmann's area or BA) of the brain also go from vertical to horizontal, thus establishing direct causality along with proof of a geometric property in activation patterns. There is very strong evidence now that topographic areas like the Primary Visual Area (PVA) or the BA are activated during mental imagery and these findings clearly show spatial relations in the patterns of activation(Klein et al. 2004 and Thompson et al. 2000). Although these tests are not relevant to the CDT in particular, it is essential to mention them since they lay the groundwork for the idea that there exists representations of images specifically in the neural architecture and impairment in that visuo-spatial architecture will have an effect on those representations which will be observable by suitable cognitive tests, like the CDT.

The other side of the debate was neatly summarized by Pylyshyn(Pylyshyn 1981) whose basic contention was that these findings were not enough grounds to warrant an entirely different theory for imagery. He argued that it is not that there is a fundamental difference in reasoning which involves images and reasoning which doesn't, but rather it is the tacit knowledge of the observer (Pylyshyn 2002) which results in certain empirical findings which are claimed as proof the spatial theory, in short these 'spatial' results are introspective, not parsimonious etc. The second line of argument Pylyshyn pursues in that paper is that our visual apparatus is physically constrained and this is what results in the quasi geometric properties of perception, not something intrinsic in the representation of images and that many of the imagery results can be explained away in terms of what he calls 'attention'. Pylyshyn also claims that the neurological data which is claimed as proof of the spatial theory is over-interpreted and there are alternative interpretations. He claims that in certain of these observations, the constraints that are placed result in the observations being interpreted as spatial in nature. In making this claim Pylyshyn is unaware of newer developments in fMRI which came up shortly after the publication of his general argument (see more recent results of Klein et al.) which show stronger relations between changing spatial properties of the object under observations, and observing spatial properties of the patterns of activation of the activated areas change. In general Pylyshyn advocates what he considers a more parsimonious approach when dealing with neurological (and otherwise) evidence(Pylyshyn 1981).The paper agrees that several of the concerns Pylyshyn and those of the descriptive school of thought raise are valid and further empirical evidence is required to decide one way or another. Even the fMRI results, though convincing are in no way final. The paper advocates using the CDT partly because of its specialized natures; the CDT was not primarily designed to test whether or not mental representations of images are spatial in nature. Since the only function of the CDT is to only test for Executive Function Deficit, and since there is neurological proof that EFD is connected with higher order reasoning, the CDT clearly displays what is of importance in visual reasoning, what gets damaged first and most when cognitive impairment sets in, and what on the other hand is fairly resistant to the most debilitating forms of cognitive impairment. There are certainly other cognitive tests which accomplish the same task, i.e. to measure visuo-spatial function, but the range of factors which are observed with the help of CDT are immense plus the crosschecking of factors CDT provides is helpful in making a stronger argument that would not have been possible in tests which isolate individual visuo-spatial factors.

The Clock Drawing Test

Clock Drawing Test (CDT) hasbeen used for decades as a neuropsychological screening test (Freedman et al. 1994).CDT is usually a part of the 7-Minute Screen, CAMCOG (Cambridge Cognitive Examination), and Spatial-Quantitative Battery in the Boston Diagnostic Aphasia Examination (Strauss 2006). CDT focuses on visual-spatial, constructional, and higher-order cognitive abilities including executive aspects (Maruish 1997).

CDT includes human cognitive domains from comprehension, planning, visual memory, visuospatial ability, motor programming and executing, abstraction, concentration, and response inhibition (Ismail and Rajji, and Shulman 2009). The major value for clinicians to conduct this test is that CDT can provide concrete visual

references of patients. This always provides good information to capture cognitive dysfunction.

Currently, CDT is administrated in a hospital environment by clinicians (Strauss 2006). Patients will draw a clock following the instruction by the clinicians. Patients will use a pencil and draw a clock in a given sheet of paper. There are two different types of testing. First, patients will draw a clock in a pre-drawn circle. This test focuses on the spatial distribution of numbers as well as hands of the clock. The other type of test does not provide any circle on the paper. Therefore, patients draw a circle using a free-drawn circle rather than a pre-drawn circle. In some cases, patients do not need to draw a circle from their memory because they are asked to copy a clock by showing a clock drawing picture. There is a case to set different time such as 1:45 or 3:00 (Strauss 2006).

There are numerous scoring systems available. The scoring systems cannot be all comparable because of differing emphasis on visuo-spatial, executive, quantitative, and qualitative issues (Kaplan 1990). The qualitative errors can provide more valuable information to understand different patterns of drawing due to the progression of dementia. For example, clocks drawn by patients with right frontal lesion shows difficulty with number position. Clocks drawn by patients with left frontal damage shows reversal of the minute and hour hand proportion (Freedmanet al. 1994). CDT is one of the most versatile tests available to directly map neural damage to impairment of visuo spatial behaviour.

Overall, CDT is accepted as the ideal cognitive screening test based on widespread clinical uses (Ismail, Rajji, and Shulman 2010). Among published studies, CDT achieves the mean sensitivity of 85% and specificity of 85% (Shulman 2010). Due to the complicated nature of screening dementia, it would be ideal to use CDT together with other types of dementia screening tools. The CDT in one of its simplest versions consists in asking the patient to draw a clock face on a circle after providing the tine to the patient. The patient needs to draw the numbers, the hands at the correct position etc. After the patient is done, the drawing is analyzed on the basis of the digits, the hands of the clock and the centre point of the clock face (Jeste et al. 2004). The factors considered in this version of the CDT are shows in Table 1.Seemingly simple; this test measures several vital parameters of visuo spatial cognitive processes. We the authors posit that the CDT presents an opportunity to sift what is resilient to what is vulnerable in context of visual reasoning. We observed that the results of these 50 CDTs are fairly consistent as was postulated and have a simple explanation if looked at from the point of view of the spatial theory of visual reasoning. Of course these consistent results might have a descriptive explanation as well but it would be far less parsimonious and would involve postulating specialized visuomotor processes which handle the internal descriptive representations. Here comes the importance of the usage of CDT. Had we used any other test, and say one factor, like the digits drawn shown such qualities, such an explanation of specialized processes would have been as valid as a depictive explanation. But it is not so here. CDT simultaneously measures many factors, not just text or digits, but shapes, sizes, their positions and angles. Unless the claim is made that each of these factors are privileged and their internal descriptions are being handled before output it is far simpler to attempt to understand these results in terms of mental imagery.

Table 1. Clock Drawing Task Evaluation Criteria

Numbers 1. Only numbers 1 – 12 are present (without adding extra numbers or omitting any) 2. Only Arabic numbers are used (no spelling, e.g., “one, two” no roman numerals) 3. Numbers are in the correct order (regardless of how many numbers there are) 4. Numbers are drawn without rotating the paper 5. Numbers are in the correct position (fairly close to their quadrants & within the pre-drawn circle) 6. Numbers are all inside the circle
Depiction of Time (Hands) 7. Two hands are present (can be wedges or straight lines; Only 2 are present) 8. The hour target number is indicated (somehow indicated, either by hands, arrows, lines, etc) 9. The minute target number is indicated (somehow indicated, either by hands, arrows, lines, etc) 10. The hands are in correct proportion (if subject indicates which one is which after “finishing”, have them fix the proportion until they feel they are correct) 11. There are no superfluous markings (extra numbers or errors on the clock that were corrected, but not completely erased, are not superfluous markings) 12. The hands are relatively joined (within 12mm; this does not need to happen in the middle of the circle)
Center 13. A Center (of the pre-drawn circle) is present (drawn or inferred) at the joining of the hand

Experiment and Observations

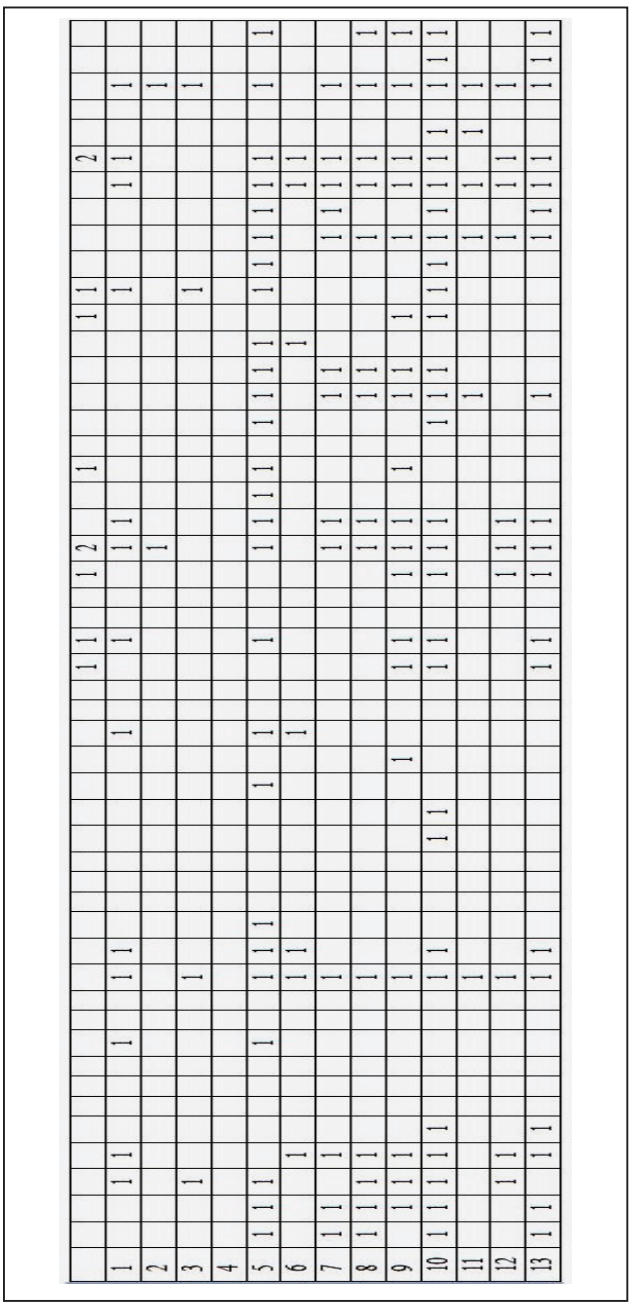
50 CDT datasets of patients were collected. These CDTs had been conducted by the Alzheimer Centre of a local hospital on a random set patients suffering from mild cognitive impairment as a result of aging. Some of these tests were progressively done on the same patients throughout multiple years. Aside from human testing, to ensure some objectivity, we used Machine Learning algorithms namely KNN and a multilayer perceptron to compare the digit themselves in the clock drawings. This was done to check whether cognitive impairment starts to

impair the basic shapes of the handwritten digits and if those handwritten figures are different from the 'normal' handwritten digit dataset (MNIST), and if those differences are uniform and can lead to some argument about visual reasoning. No uniform differences were detected apart from a lack of legibility of those digits which are proved to be a problem for the ML algorithms. Apart from legibility, impairment of the Executive Functions seems to leave the faculty of drawing handwritten digits quite intact, and in most (if not all cases) the digits were understandable by the human observer. In most cases the digits show a surprising amount of authorial consistency over the period of years with increasing (or decreasing) impairment, retaining their basic characteristic. The general observation is that impairment in Executive Functions (thus higher order visual reasoning) has little to no effect on an individual's handwriting compared to the massive differences in their spatial reasoning, ergo 'shapes' are easier to mentally represent than 'sizes'. This helps in the claim of spatial reasoning that shapes are functionally represented internally and *not processed from descriptive data*. Looking at this from the opposite point of view if the shapes are represented internally as descriptions instead of depictions, then there exists some sort of specialized mechanism to convert those descriptions to shapes robustly. However if such propositional architecture is being used then these properties would remain confined to the digits. It is not so. Not only are the individual shapes of the digits retaining consistency, but the circular arrangement in which the digits are to be drawn being preserved over the range of patients. The patient may lose the concept of magnitude, centre, or eccentricity of the ellipse or circle, but would invariably try to place the digits in a circular arc, even if having a high degree of cognitive debility and displaying errors in every other factor. Even when drawing outside the circle provided or shrinking the spacing between the digits too much, the basic idea of a circle is preserved. Thus the shapes are preserved over the subparts of the clockface and the clockface in general.

Table 2: Overall Incorrect Instances per CDT criterion

Criteria	**Incorrect instances**
1 – 12 are present	13
Only digits are present	2
Correct order	4
No rotation (assume correct)	
Correct position	26
Inside circle	7
Two hands present	13
Hour indicated correctly	14
Minute indicated correctly	19
Proportions of the hands	28
No extra marking	6

Table 3: Observation Chart



In the table 3,each column represents a drawingfrom the 50 CDT test cases. Some patients have been repeatedly tested. Each row represents a criterion of the CDT with respect to table 2; however the top row was used to make comments. The digits '1' and '2' in that row meant that the patient was unable to convert between the concept of minutes and hours, '1' means the patient marked the minute hand using a number meant for hours, i.e. if the time given id 11:10 the patient pointed the minute hand at the figure 10.Figure 1 shows two different examples which incorrectly indicate 11:10.

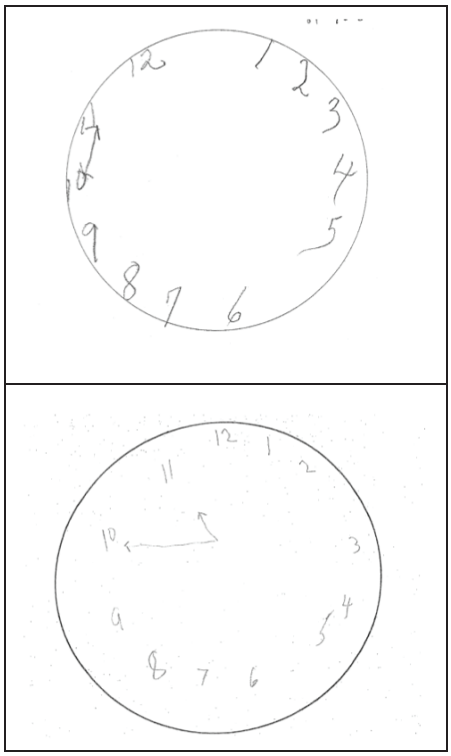


Figure 1. Examples of Incorrectly Indicating 11:10

'2' means the patient pointed the hours correctly and wrote the minute value with it rather than using the second hand. It was observed that the majority of the errors were among the positioning of the figures and the centre, while there was little to no error, even among patients with a relatively high degree of cognitive impairment, as far as the ordering of the digits were concerned. Almost all of the patients display a surprising lack of errors when it comes to the individual symbols themselves, for example they almost always make their digits recognizable. The frequency of errors is most in spatial factors, dealing with angles, distances etc and least with the actual figures of the digits themselves. Though at times too illegible for the machine learning software (40% times not recognized correctly), they are always almost recognizable by the human observer. On the other hand, the errors are most in placement of the figures and in the location of the centre. Similarly the errors in recognition of the digits are mainly due to incorrect linear distances within the digits. Thus these drawings display not only the 'correct' factors being replicated on a micro as well as macro scale but the 'incorrect' factors similarly replicated. Although the errors are most in 'position' what that means is that while the patient tries to maintain the concept of the circle he/she invariably varies the magnitude of the spacing between the digits, resulting in one semicircle being sparse. It is very rare when the ordering itself is incorrect, or when there is no semblance of a circle. In fact there were only a single patient and two drawings of the same patient who had no semblance to a circle. Also that patient got almost every other thing incorrect.

This reinforces the thesis that it is far easier to reason about concepts like ordering of elements in a figure than to reason about the position of the subparts of that figure. Now had the internal representation of the clock face been propositional (descriptive) in nature these results would have been quite different. Going with our hypothesis that CDT measures higher order debility first the higher order propositions or descriptions would have been damaged first.

If we ignore the ordering (as it may have been preserved due to being a specialized form of internal representation) the general characteristics of the clockface should have been damaged and the smaller characteristics like mutual spacing between two numbers or the hands should have been resilient. It is the other way around. Most of these drawings 'look' like clockfaces. The patients got the proportions and the positions incorrect, but preserved the general shape of the clock, its digits and hands.

The observations also yielded some surprising results which can have implications in other forms of higher order reasoning and how they interact with imagistic reasoning. As mentioned earlier some patients, when asked to draw the time 11:10 draw the hours hand correctly at 11 draw the minutes hand at the digit 10 rather than at 10 minutes. This trend in those specific patients continues over the years or worsens when they become incapable to distinguishing between the concepts of hours and minutes and it reflects in their drawings. Though it is advisable to avoid post hoc reasoning and it is still unclear whether these results is a consequence of the CDT itself or are those patients a specific subset who have an impairment in some other higher order reasoning (linguistic) faculty, which is influencing their CDT output. Furthermore, this observation could be due to the patient's inability to correctly interpret the command instruction asking them to point the time 11:10. Patients tend to make such stimulus bound errors because their information processing is more a perceptual level rather than a semantic level (Freedman 1994).

In a more detailed manner several other trends were displayed by the majority of the patients used to generate the 50 test cases. The size of the curves made by the patients in individual digits show rather less amount of changes than size changes in linear distances among those digits and inside those digits over the period of time. This is consistent with the observation that curves are more resilient that straight lines. Almost every patient shows some error (except those who show no error) in placing the digits on the circle uniformly. Similarly the proportion of patients who get the sizes and/or angles of the hands wrong are quite large.

The results when viewed in the context of the two theories of visual reasoning make a lot of sense. If the descriptive theory been correct it would have meant that shapes need to be computed in any figure, as figures would have been stored in a language like manner. Since we can describe a

shape with a very few constrains (say the figure '6') in an *infinite* number of ways, it stands to reason that had there been processing involved in representing shapes, they would have been the first casualty of cognitive impairment. As it is observable this is not the case. Shapes are one of the resilient, if not the most resilient factor in visual reasoning according to these results. If we combine that with the resilience of ordering, and postulate that sketches are internally represented as the ordered (temporally) set of their parts, it becomes a strong support for the spatial theory of visual representations. When we mention shapes here we mean the individual digits, the shape of placing those digits in the circle, and the two hands. Even if in isolation each could be explained away by a specialized internal mechanism to convert propositions into output, it is unlikely that all there would be a specialized mechanism for preserving the shape of a circle of a clock. Surprisingly this has been the same case with those CDT's where the original clock circle is not provided (unlike the test we did).

Figure2shows three different clock drawings from one patient from 2008 to 2009. The drawing clearly shows the degradation of patient's cognition. Interestingly, the patient could not use the space of the clock evenly.

P22: Clock drawing task was performed on June, 2008	
P22: Clock drawing task was performed on January, 2009	
P22: Clock drawing task was performed on June, 2009	

Figure 2: Clock Drawings through three years

It was observed that digit recognition of patients with cognitive impairment is much easier if we focus on the *geometric aspects* of the sketches rather than just use ML, as geometric properties show their ubiquity whether the patient undergoes an improvement in their condition or not throughout the years. And this combined with all the other data can lead to a conclusion that primarily internal representation of visual concepts are geometric in nature.

To conclude our analysis of the observations, they show a surprising uniformity in certain properties, e.g. patients with very low scores consistently display that they are at ease with basic shapes but not with distances or proportions. Impairment in executive faculty leads to degradation in the capacity to process images but only in a specific manner which is much easier to understand if the theory of visual representations is used rather than that of propositions. To explain these results by the descriptive theory would not only necessitate existence of various internal specialized mechanisms to deal with the lot of aspects of drawing a clock, it would necessitate the rather bold assumption that these mechanism start to get impaired in a specific pattern when EFD starts to set in. However it is necessary to pay attention to some of these observations which can have a slightly different interpretation. The ease of getting the smaller parts of the image correct and missing out on the lager spatial properties, and that too repeatedly, could also be due to a connectionist internal representation where 'context' is more important than 'content'(Smolensky 1988). This would mean that such specialized resources do exist internally and work by a network like structure, and the cognitive damage is thus distributed over them producing specific pattern. That would of course be a post hoc observation but a possible area of investigation. If the connectionist school of thought (Smolensky 1988) is correct then it is not the shape themselves which are persisting but the elementary parts of those shapes which are leaning towards correct ordering, thus cognitive impairment, while damaging the combination of those parts, doesn't damage the parts themselves. An argument could be made that the data observed does show that basic shapes are more resilient than sizes as far as internal representation go but this is so because the damage to the neural architecture is confined to those areas which govern spatial reasoning, and that the neural architecture itself, with its weights etc, is relatively undamaged. Since no connectionist theory justifies itself in isolation from any higher order conceptual mappings (with its 'subconceptual' mappings) (Smolensky 1988) the conclusions are still quite relevant. And although such a discussion is beyond the scope of our work we believe there is scope for further investigation in this direction. It does not matter which theory of internal representation is correct (or a combination of them) in either case the CDT proves to be a valuable generator for empirical results due to its ability to produce a large collection of visuo-spatial data having a wide range of properties to test for subsequent divergence. Since the CDT has often different rubrics, and is even used for different set of ailments, it

could theoretically be used as a tool for tests involving other kinds of higher order relations (not just the imagistic kinds) mapping them with the current hypotheses of the cognitive effects of the diseases in whose context those rubrics are used. As the cognitive effects of such diseases are well documented it is easy to establish causality. Thus the CDT could prove to be a powerful cognitive tool in addition to it serving its present purpose.

Conclusion

The paper presents the two main schools of symbolic representation of images, and compares and contrasts them. It postulates consistent observations on performing the CDT on patients with cognitive debility, having mapped impairment of EF to visuo-spatial functions. The observations of the CDT tests do show such consistency in factors which are uniformly correct and the factors which are uniformly erroneous. Our analysis of the observations lends support towards the depictive school rather than the descriptive school, and though other explanations would exist it would necessitate postulating a lot of internalized specialized mechanisms. We have presented our case as to why CDT can be used as an important tool in generating empirical data to test these theories. The CDT dataset of 50 test cases of patients suffering from cognitive impairment is analysed and the observations are consistent across the spectrum of patients suggesting that shapes are not processed in their internal representations; rather, they are represented in an analogous manner. These observations are consistent in the macro and the micro level of the drawings, thus the shapes of the digits as well as the shapes of the clock faces are preserved; the linear distances in the digits as well as the linear distances between them show high error rates. . Thus in totality the paper presents its case for using CDT as a tool for testing cognitive theories of internal representations.

Acknowledgments

We would like to thank Health Systems Institute at Georgia Institute of Technology and Emory Alzheimer's Disease Center to their financial support for conducting this study. We also like to appreciate volunteered people for CRIN (Clinical Research in Neurology) to provide us valuable data.

References

Elliott, R. (2003). *Executive functions and their disorders. British Medical Bulletin.* (65); 49-59

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. Cambridge, MA: MIT Press.

Freedman, M., L. Leach, et al. (1994).*Clock Drawing: A Neuropsychological Analysis.* Oxford, Oxford University Press.

Ismail, Z., T. K. Rajji, et al. (2010). *"Brief cognitive screening instruments: an update."* Journal of Geriatric Psychiatry 25(2): 111-120

Jeste D.V., Legendre S.A., Rice V.A., et al. (2004). *"The clock drawing test as a measure of executive dysfunction in elderly depressed patients."* Journal of Geriatric Psychiatry and Neurology.

Kaplan, E. (1990). "The process approach to neuropsychological assessment of psychiatric patients." Journal of Neuropsychiatry 2: 72-87.

Klein, I., Dubois, J., Mangin, J-F.,Kherif, F., Flandin, G., Poline, J-B., Denis, M., Kosslyn, S. M., and Le Bihan, D. (2004). *Retinotopic organization of visual mental images as revealed by functional magnetic resonance imaging*. Cognitive Brain Research, 22, 26-31;

Kosslyn, S. M. (1994). *Image and Brain: The resolution of the imagery debate*. Cambridge. MA: MITPress.

Kosslyn, S. M., Ganis, G. and Thompson, W. L. (2001). *Neural foundations of imagery*. Nature Reviews Neuroscience

Libon, D., S. RA, et al. (1993). *"Clock drawing as an assessment tool for dementia."* Archives of Clinical Neuropsychology 8: 405-415.

Maruish ME, ed. (1997).*Clinical Neuropsychology: Theoretical Foundations for Practitioners.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Pinto, E. and R. Peters. (2009*). Literature Review of the Clock Drawing Test as a Tool for Cognitive Screening. Dementia and Geriatric Cognitive Disorders.* 27(3): p. 201-213.

Pylyshyn, Z. W. (1981). *The imagery debate: Analogue media versus tacit knowledge*

Pylyshyn, Z. W. (2002). *Mental Imagery: In Search of a Theory* Cambridge University Press

Rabins, P.V. (2004). *Quick cognitive screening for clinicians: Mini mental, clock drawing, and other brief tests.* Journal of Clinical Psychiatry. 65(11): p. 1581-1581.

Shulman, K. (2000). *Clock drawing: Is it the ideal cognitive screening test?* International Journal of Geriatric Psychiatry. 15(6); 548-561

Smolensky, P. (1988). *On the Proper Treatment of Connectionism,*Behavioral and Brain Sciences, Cambridge University Press

Strauss, E., E. M. S. Sherman, et al., Eds. (2006). *A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary*, Oxford University Press.

Thompson, W. L. and Kosslyn, S. M. (2000). *Neural systems activated during visual mental imagery: A review and meta-analyses.* In: A. W. Toga and J.C. Mazziotta (Eds.), *Brain mapping II: The systems.* Academic Press, San Diego.

Van Essen, D.C., Lewis, J.W., Drury, H.A., Hadjikhani, N., Tootell, R.B.,Bakircioglu, M., & Miller, M.I. (2001). *Mapping visual cortex in monkeys andhumans using surface-based atlases*. Vision Research*, 41*, 1359-1378.