Learning to Cooperate is Essential for Progress in Physics

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Abstract. At the 10th Frontiers of Fundamental Physics symposium, Gerard ’t Hooft stated that, for some of the advances we hope to see in Physics during the future, there must be a great deal of cooperation between physicists from different disciplines, as well as mathematicians, programmers, technologists, and others. This requires us to evolve a new mindset; however, as so much of our past progress has come out of a fiercely competitive process – especially since a critical review of our ideas about reality remains essential to making clear progress and checking our progress. We must also address the fact that some frameworks appear incompatible, as with relativity and quantum mechanics, whose unification remains distant despite years of attempts to find a quantum gravity theory. I explore the idea that playful exploration, using both left-brained and right-brained approaches to learning, allows us to resolve conflicting ideas by taking advantage of innate human developmental and learning strategies and brain structure. It may thus foster the kind of interdisciplinary cooperation we are hoping to see.

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INTRODUCTION

When Professor ’t Hooft spoke, in the closing at last year’s conference in Australia, about how both greater cooperation and broader collaboration are necessary to our progress in Physics, he was giving voice to an idea I have believed in and expressed for years. Hearing this message from such a distinguished speaker, however, reminds us that divisive competition which prevents cooperation and collaboration is a known problem in Physics, and made me feel it is timely to share what I know on the subject. It is appropriate that the 11th Frontiers in Fundamental Physics conference was in Paris, because what first brought me there, about 15 years ago, was my skill in fostering cooperation between groups from dissimilar backgrounds, with different goals, for a common purpose. I was sent there to help train European dealers and their technical staff to use the Graphics workstations I had helped to develop. In the meanwhile; I have done considerable research on the cognitive basis for skills and activities necessary for cooperation, and the dynamics of competition. What kills cooperation faster than anything else is an ‘us against them’ mentality. Unfortunately; this is very common, in Research. Groups researching various subjects compete for a piece of what appears to be an ever-shrinking pie, and the spirit of competition overwhelms any thoughts that cooperation and collaboration might be desirable.

It is possible to turn this situation around, and not nearly as difficult as it seems. To understand how; we need to consider how the brain works, and how we developed the mental capacity for activities like Physics, which are intensely cerebral. This matter is summarized well by Joseph Chilton Pearce [1]. The trick of using the brain's structure to our advantage is keeping our daily affairs in the arena of exploring possibilities as much as possible, which moves our attention into the neocortex, and avoiding judgmental or confrontational interactions which may put people 'on the defensive' or force their attention to move into the 'reptilian brain' instead of the upper cerebrum. This is the root cause of much of the cunning or callous behavior among scientists, resulting from stiff competition, unreasonable demands for results or progress, and the need to prove oneself at every step in the process. However; becoming defensive is an adolescent response to the problem, rather than that of a mature adult. Sometimes there are conflicting demands, as the needs of the research and the interests of one's employer or sponsor pull a person or research group in very different directions. If one cannot rise above the emotional turmoil generated by conflicting goals, and remain somewhat philosophical about the outcome of events, this also moves one's own attention into lower brain centers, which again robs us of some of the creative and imaginative faculties that could actually solve problems.

Attempting to combat this directly is risky, as it perpetuates the 'us against them' mentality which caused the problem. In a way; what we need to do is simply to behave as adults, rather than allowing ourselves to be drawn into the adolescent behaviors of others, regardless of their position on the hierarchy. The fact that some leaders are not sufficiently refined or adult is no excuse for us to behave that way, nor does it absolve us of the need to treat others with equanimity. I will leave ethical issues aside, for the moment, except to say that real cooperation requires a sense of 'fair play.' And when all things are considered; scientific research is like play, or is play – compared to most other gainful or productive activities. Scientific researchers have the best toys, and the most open-ended agendas of all those engaged in professional careers. Make no mistake; Science is 'serious play' where silly nonsense is not allowed, and it is also 'adult play' rather than 'child's play,' as it is mutually consensual. But doing Science can be a lot of fun! I had the occasion to spend some time with one of the conference organizers, Padma Kant Shukla, in the airport when traveling to and from last year's event, FFP10. And I must tell you that his joy from doing and talking about Physics is palpable and infectious. I am quite certain that scientific research is like play to him – and that he has a lot of fun doing it.

So is this something the rest of the community can learn from, and emulate? Unfortunately; few of us share his unabashed exuberance, but a 'sense of wonder' about how the universe works is more or less essential to what we are doing, and the sentiment can indeed be caught from others who have the same feeling. I am sure most of you have been inspired this way, or have touched others when talking about your work. Sharing the wonder fosters cooperation and enables collaboration. This is another activity which moves our attention into the neocortex, and assists in our exploring possibilities. Conversely; fear and apprehensiveness about sharing our ideas involves the older 'reptilian' brain structures, and moves our attention out of the cerebral cortex. Obviously; that can't serve us, or does not foster the kind of brain activity that leads to advances and breakthroughs for Physics. Thus; it is easy to see how playful exploration assists cooperation and collaboration, and promotes the kind of intellectual activity which leads to advances, while a refusal to play with others has exactly the opposite effect. It appears, from this last point; that playful exploration is essential to fostering the cooperation which leads to scientific collaborations.

The preceding has shown that a very basic understanding of how the brain works reveals the dynamics which foster cooperation or promote antagonism, and suggests that playful exploration helps us by allowing an individual to remain active in the cerebral cortex more of the time, increasing their willingness to ‘play’ with others. This is clearly more important in Physics than in many other fields, as what we do demands that we engage our neocortex fully – and disengage somewhat from lower brain activity. In the remainder of this paper, I discuss the dynamics of play in more detail – showing what helps to foster cooperation – and I explore how understanding the lateralization of brain function may also aid cooperation, as it suggests innovative and unique strategies for solving thorny problems which remain too difficult for any of our finest minds to solve alone. For example; reconciling Relativity with Quantum Mechanics might be a conundrum which requires the full engagement of both brain hemispheres by multiple individuals to solve, because of the nature of the problem. My own recent Physics involvement has shown me how deeply fragmented, polarized, and stratified entire fields of study have become. But isolated ‘silos’ of knowledge do not aid the common understanding, and are a barrier to collaboration and the integration of information. Fixing this is important work, therefore.

PLAYFUL EXPLORATION

Exploration begins early for human children, along with play which happens as soon as they discover there is something or someone to play with. The constancy of objects must be apprehended first. A very young child will cry when Mommy goes into the next room, or when their favorite toy is put away, simply because the object of their attention is not immediately apparent. Once they understand that their mother and their toys still exist even when not visible, that sets the stage. The next phase of cognitive development happens when they become mobile, and is characterized by a cycle of - observe, explore, and compare - which repeats almost endlessly. I see this as an attempt of the brain to calibrate itself, while simultaneously learning about its surroundings or environment. In one published paper [2], I take the view that this is analogous to the way evolving a measurement procedure also creates a constructive framework in Constructive Geometry, which explains the results of research into the roots of symbolic thinking by Judy DeLoache [3, 4, 5]. She observed that children below a certain age display a sort of dimensional confusion, where they might attempt to put on shoes that are much too large, attempt to sit on a small toy chair, or converse with a photograph, mirror image, or TV screen. That confusion goes away at around two and a half years of age; at which point symbolic reasoning begins to develop.

It is my idea that the ability to determine dimensionality is itself the gateway to all higher learning, as this is what allows us to entertain a dual representation of reality. Therefore; it is no accident that Gerard ’t Hooft’s paper on “Dimensional reduction” [6] (which introduced the Holographic Universe concept to Physics) remains one of the most downloaded papers of all time. As soon as people found it on the arXiv, there was a flood of papers, assisted by Susskind's work [7] and Maldacena's generalization [8] of 't Hooft's findings (to other dimensional boundary transitions), the likes of which has not been seen before or since. This idea clearly re-capitulates and expands upon the same notion which first enables us to think symbolically - that information which is 'written' on a 2-d surface can represent entities in or qualities of a 3-dimensional reality - and it now serves as a general way to translate between dimensional frameworks in Physics. At least in this one instance; the progress of Physics is seen to be an extension or outgrowth of an important step in evolutionary and cognitive development. But it would be safe to say that all progress in any of the sciences requires the development of our higher cognitive faculties, where progress is therefore dependent upon the nature of those faculties, being determined by the way our cognitive abilities develop.

What seems to facilitate our learning and development best is playful exploration. Joseph Chilton Pearce and Michael Mendizza have made it an important part of their life's work to champion the value of play and indeed the intelligence of play, as a learning tool, both in the educational community and for a larger audience [9]. Their work strongly suggests that peak performance in any endeavor requires a sense of playfulness, and that play is absolutely essential to the proper development of the young mind. Both gentlemen assert that playing is the optimal activity for retaining what we learn, and have said it is perhaps the only way that we really do learn. Part of what must be emphasized here (to understand how this relates to scientific research) is that trying different things is important to do, regardless of success or failure. This stands in stark contrast to the idea that one's activities are worthwhile only if they bring results. The example of Edison with the lightbulb is important to consider. He tried hundreds of candidates before he chose a tungsten filament as the core of his invention. If he was instructed to play around less, and just make something that works, we might have had inferior lightbulbs – or seen their development only years later. So; it was Edison's willingness to play that got us something that really works. And so it is with many important inventions and innovations.

It is much the same in Physics. If we are not willing to play around with different possibilities, to some extent, we are not nearly as likely to discover or develop something of value – as someone who does have a playful attitude. This was a central point in Doug Osheroff's talk at FFP10 "How Advances in Science are Made," but the same idea found its way into the talks of both John Ellis and Anton Zeilinger, at FFP11. Some people like to think of this in terms of taking risks, but I assert that the real issue is the openness to new possibilities, or the willingness to try things which might work, rather than simply doing risky or foolish things. One must proceed with the understanding and assumption that something you are looking for may happen, or may work out, but then be prepared to accept what does happen, what the numbers really say, and so on. That is; one must first have reason to believe there is something interesting that deserves to be examined, then one must actually explore the possibilities you have imagined. If you are unprepared to approach nature playfully, you will never discover her secrets. Unless you are willing to try a large number – or a wide range – of different things during your experiments, you may miss out on the opportunity to actually find what you are looking for.

There are many stories of the other guys, the folks who almost made an important discovery, where the ones who did so tried something a little different. It appears that the spoils often go to the playful – to those who were a little more creative and inventive, or who were perhaps willing to try one more thing, even if it was a little odd. By playing around with different things until the right combination was found, many great discoveries and important advances came to be. And so it will always be. Mind you; there have been all kinds of advances that came out of systematic and careful work, which was well-documented; and then showed researchers something exciting. But without some innovation, and without looking beyond or outside of what has already been examined, many discoveries and advances would have been and will remain absolutely impossible. So being playful, and engaging in work as play, are of considerable value for scientific research. The benefits from playful engagement of the scientific process are many and obvious. But being playful about your work will not – of itself – foster a playful work environment or allow for playful engagement with other researchers. Nor will playfulness guarantee cooperation and facilitate collaboration. That requires something more - a sense of fair play.

FAIR AND ADULT PLAY

It seems that everyone wants to be treated fairly, and as an adult. It would be nice to say that bright and capable individuals who work hard and play fair are always treated fairly and with respect - in a research environment. However; this is difficult, as there will always be those individuals who will do whatever it takes to accomplish their goals, even if that means marginalizing others in order to advance their own cause. And there will always be unfair systems which fail to reward honest hard work, talent, fair play, or even impressive results. So I have seen people I greatly respect get treated poorly, tremendously bright and talented people get marginalized, and professionals who always play fair and treat everyone with respect get pushed around or pushed aside, as they become victims of others who are more ruthlessly ambitious. But, by and large, people in Physics are indeed more refined and adult than people in most other professions. Perhaps it is the fact it requires so much effort, and takes so long to become established in a field of research, that there is a certain amount of respect automatically garnered by those who have made, or are making that effort. In some cases, people are simply so pleased to have work in their chosen field, that they don't wish to offend or alienate those they might need to work with, nor do they want to jeopardize their chances of keeping a job they worked so hard to earn.

Fair play is therefore an essential pursuit, where cooperation is required. Having the ability to play fairly is more or less essential for any kind of collaborative efforts to be successful or beneficial for all involved. Having a sense that one's own efforts are going to be treated fairly may be essential to an individual's full engagement of the process, or their commitment to the goals of the group. This could concern applying for a position or one's performance reviews by employers, the acceptance or rejection of academic papers for publication, opportunities to present at a conference, or consideration for grants and other sources of funding. If we think we are likely to be treated fairly, we are more apt to give such things our best effort. This certainly applies to our commitment toward any sort of collective venture that requires or benefits from, our cooperation. If we feel that we might share in the rewards – when people are rewarded for their efforts – this is likely to spur us on, or to provide an extra incentive for continued and/or increased effort. But if we feel that the rules of the game are unfair, seeing that some people are treated fairly and rewarded where others are not, this can serve as a disincentive, as it trains people to be less helpful or supportive of the group's goals and more concerned with getting their due.

I was in a Physics essay contest sponsored by the Foundational Questions Institute, on "What is Ultimately Possible in Physics?" I made a strong effort as I wanted to make the best possible showing regardless of the outcome, but felt also that I needed some of the prize money to offset the large expense of traveling to Australia for FFP10. I thought that, if things were handled fairly; I at least had a shot at winning something. In addition to writing an essay [10], I answered the comments and questions as they poured in on the forum provided, as well as accepting many invitations to read and comment on other people's essays. And it was a lot of work, but very intellectually stimulating – to say the least. Overall, I found it was a rewarding experience, as I got to have numerous conversations with people who had a great range of wonderful ideas about Physics, many of whom were far more erudite than I, having more advanced degrees, journal publications, and so on. There were world-class scholars among the entrants, many of whom actually participated in the on-line forum – addressing the questions and concerns of the other entrants and the general public. All I know is that several ideas which were beyond my ken at the beginning of the contest were explained in detail by their authors, just as I took the time to explain ideas in my own essay. And I went on to explain other people's ideas too (Daryl Leiter's for example – who shared my explanation with others).

When the voting drew to a close, for the essay authors and FQXi members not judges, I was one of the top finalists – 3rd in a field of 114. Since a large number of authors in the essay contest were professional scientists, with hundreds of academic papers and one or more books published (where I am not and have not), this result both pleased and impressed me. I was both surprised and elated then; however I was as surprised and disappointed – not being among the winners – when the final results were announced. Do I think things were handled fairly? I'm honestly not sure, though I believe they tried to be fair. Since they only announced the winners, and never posted the final rankings, I don't know exactly how I did. All I can tell you is that those who did win were professional researchers. Two of the presenters at FFP10 told me they had participated in an earlier FQXi contest, and would not likely enter another one again. The same is true of some folks who entered the same essay contest I did. The sense of fair play (or fair opportunity) being absent, in the minds of those individuals, makes their involvement appear like a waste of time. So there are some lessons to be learned from all of this. If it is a game, I reason that the only way to win is to play, so I would do it again.

There were some lingering spin-offs of the FQXi contest, in the form of numerous new friends and acquaintances, insights into fields of study I had not pondered before, and answers to questions I had about fields I have already studied. So it was not a waste of time for me, nor do I feel resentful of the outcome – though I wish it were more transparent. Recent experience has shown me that sometimes the harsh comments of an expert peer-reviewer are exactly what I need to put me back on track. In other cases, however, I have to wonder if a reviewer's comments reflect a bias that won't admit new data. I had occasion to read the content of, and the reviewer comments for, a colleague's paper which was rejected for journal publication. The data used (SDSS and 2dF) are publicly available, the researcher's analysis was careful and thorough, and he is a full professor at a prestigious university. He merely searched the data for patterns others hadn't looked for before. And the reviewer's comments echoed the sentiment that the author should stress that what he observes is in disagreement with the predictions of the concordance model, arguing that he must show the observed result is plausible in theory. It seems unfair to need to show how it happened, before you can tell what you observed. I have since seen several papers which offer a plausible mechanism for the observed pattern of data. But what this says to me is that when a sense of fair play is absent, it is a barrier to progress.

This brings us to the topic of 'adult play,' and how we distinguish this activity from 'child's play' or 'adolescent play.' Part of the story involves moving from dependency to more self-reliant and independent behaviors, as we mature. Human children are completely dependent on the care of others, at birth, as they need both provision for their basic needs and nurturing of their skills and cognitive faculties. The importance of this nurturing cannot be over-emphasized, as it is their doorway to higher development. If you believe in the vision of Pearce and Mendizza, children are born 'magical' – with almost unlimited potential. However; they take on inhibitions in response to the disapproval of their role models. Take for example, the fact that when very young children are asked to sing, or invited to sing along with an adult, almost every one will chime in – and sing along with the group. But if the same experiment is repeated with older children, an increasingly large percentage of the group will be silent, or will need to be coaxed to sing at all. Once children are told they sing badly, or that they are 'doing it wrong' too many times, they are much less likely to open their mouths after that experience. So the way to encourage their development is to nurture their efforts and their exploration, even if at first they are doing things poorly.

While human children are dependent, adolescents are rebelliously independent, and full adult humans are cooperatively independent. To an extent; understanding what makes someone fully adult is a matter of understanding the full meaning of the word interdependency, as it applies to human needs and relations. When it is grasped that we are all in the same boat, sharing common needs, the idea of cooperative action comes more naturally. So this is how one can distinguish 'adolescent play' from 'adult play.' Adult play tends to emphasize those situations where all gain, and to evolve 'win-win' strategies, as a result. Adolescent activity, by comparison, is typically rebellious – which means that it is opposing or 'against' something, rather than advocating and being 'for' something. This is the key point of this entire paper. Whether offensive or defensive, oppositional posturing creates distance, but is a game we should outgrow as adults. As I said earlier; the impulse to oppose or defend against what is 'bad' or 'wrong' originates in the lower brain centers, or what is sometimes called the 'lizard brain' while our capacity to create the 'good' or 'right' rests in the neocortex, until we put it to use. This distinction is a reliable indicator of what distinguishes 'adolescent play' from 'adult play.'

It seems that adolescents like to play 'win-lose' games best, as a scenario where they can actually defeat someone else is superior to merely gaining accolades for oneself. Adults usually have a somewhat different agenda, where 'adult games' tend to be 'win-win' oriented or about 'improving your personal best,' as mutual consent and participation are important. To an extent, adolescent play is good and helpful to the academic process, as it fosters a sense of healthy competition where those who play the academic game are constantly honing their skills in order to get better at what they must do to excel. Thus the need to 'prove oneself' in a competitive environment does promote higher learning, and the development of academic skills and mental faculties, up to a point. But the complete development of the neocortex requires that our emphasis be shifted there as much as, and as early as possible. This means learning the rules and value of 'adult play.' Those of us who had nurturing encouragement while we were making this transition are better and smarter people for it. We are also far better equipped to engage in cooperative activities and collaborative efforts than those who were pushed back on their heels, and had to 'hunker down' or become 'cunning' to survive. The skills of fully adult play can be learned, but we need to be nurturing of the individual and the process, no matter how late in life they outgrow their adolescence.

TWO SIDES TO EVERY STORY

When examining what is required for the cooperation required to advance Physics, it is wise to remember that there are two sides to every story and two sides to the human brain as well. Whenever there are two different people, there will be two viewpoints. But the same holds true for any one person, if we acknowledge that in every person's skull there are two entirely separate brains. Not only do our two brains have different viewpoints, they tend to develop quite different skills, as well. Rather than looking at this as a source of inner conflict, however, it is wiser to think of possessing a split brain as having a built-in 'second opinion' or a 'trusted friend who will always show you the other side of things.' Though Physics is highly analytical and therefore tends to be a heavily left-brained pursuit, I argue that using both brains is absolutely necessary to complete cognition and the solution of certain classes of problems. The perception of the right hemisphere allows us to see the unifying factors and the overall scope and flow of things, while the left is more concerned with keeping track of all the details. So when we go from analyzing the data to pondering what it means, we need to allow the right-brain to be dominant for a while, as the left hemisphere is largely incompetent in this area.

In a recent paper, which I expect will soon be published [11], I explore the idea that the two halves of the brain operate as though they are doing the same thing in opposite directions of time. So they embody complementary modes of a single function. All creatures encounter directional processes, as they move forward through time, and all vertebrates display lateral specialization of cognitive function. But this lateral split is even more helpful for humans, as it assists the process of abstraction, and other higher cognitive functions. Deliberate use of both brains can be especially useful in Physics.

But coming to an understanding between the two brain hemispheres within one's skull requires many of the same skills one must develop to communicate with another person, as they have distinct personalities. By far the most important skill, for either kind of communication, is the ability to listen. But it seems that being able to engage the process playfully helps here too. A key thing to remember is that there must be a conversation for real communication to take place, but since the dominant half of the brain is generally the side that speaks; it may take prolonged silence before the sub-dominant hemisphere actually 'speaks up.' A threshold is generally reached after 45 seconds of quietude or less, when the right-brain (typically) begins to express itself, but that length of time can seem like an eternity to those who have never engaged in any sort of meditative practice.

When neuro-physiologist Jill Bolte Taylor had a stroke, she experienced first-hand what she had seen many times in her patients and research subjects, as her left-brain shut down due to a stroke, and she was pushed into right-brain awareness forcibly. After much struggling, she was able to summon help, and then recovered her full faculties years later. But her stroke experience [15] left her with powerful impressions and keen insight into the right-brain's state of consciousness. She is convinced that a significant portion of the experiences meditators seek or experience can be found in a person's right-brain, or non-dominant hemisphere, and can be explained by its activity. She documented and described this state in great detail, mapping out some of the previously overlooked connections. One connection I think is especially profound is that right-brain awareness can improve or augment our understanding of Quantum Mechanics. Specifically; the right hemisphere sees a unified and timeless reality, and identifies with the energetic and/or wave-like nature of systems and processes, rather than the particle like world of separate objects. Jill Bolte Taylor's description of that outlook, in her book and TED talk [16], reminds me of what is said in H.D. Zeh's papers "Quantum discreteness is an illusion" [17] and "There are no quantum jumps, nor are there particles" [18]. All describe a continuously evolving unified state from which emerges the appearance of separate entities.

Now, if we are seeking a route to unifying our description of reality; it might be good to start with seeing how nature is already unified, and also helpful to utilize that portion of the brain which is designed to present and process information in that way. If we want to unify two dissimilar views (Relativity and QM), which appear incompatible though complementary, we should consider that we might need to use both halves, and in fact may need to integrate the different paths to understanding recommended by the two brain hemispheres. While there are a few experts like Zeh who can speak about a very right-brained view of reality in a way that is completely satisfying to the left-brained or analytical thinkers, most of us are not able to process the insights of the right-brain in an intellectually satisfying way. Some feel that those insights are beyond description in words and symbols, but I believe this is only partially true. Rather; it is extremely difficult to translate the language of the right-brain into terms that are left-brain sensible. Kodish and Pula suggest [19] that perhaps we could play with phrasing; speaking of 'change thinging' instead of 'things changing,' for example, might make our words right-brained or Quantum accurate. This bears further examination.

CONCLUDING REMARKS

During the time since the journal publication on which this current paper is based [20] quite a lot of additional work has come to light, in support of its thesis. Perhaps most notable is the notion that very young children behave very much like scientists, by forming theories and then testing them by planning and executing experiments, which has come out of research by Alison Gopnik, who published an article in Scientific American [21], her colleagues, and others. It has also been the author's pleasure to serve as a guest editor for a special feature of Prespacetime Journal – along with Philip Gibbs – focusing on Cosmology and Gravity. Seeing how facilitory my editing work was to some of the authors I assisted was humbling. I did not imagine that veteran scientists with hundreds of publications would have a hard time getting a quality paper published. Nor did I expect to find that others creating a similar quality of product would find it impossible to get their first paper published. But I found that we had so many outstanding contributions, that even with the Cosmology and Gravity feature expanded to two special issues [22, 23], it was impossible to publish all of the good work that came our way for one. My experience shows me just how many feel isolated or neglected by the scientific community, at this point.

If the capacity for Physics to make progress in certain areas rests with our ability to cooperate, some of the ideas expressed above are essential concepts, which must be digested if we are to realize that goal. When Professor 't Hooft spoke of cooperation being needed; he was perhaps more emphatic, suggesting that if some advances were ever to come, it would only be through collaboration which was both broader in scope and deeper in content than what we have seen in Physics before. An unprecedented level of cooperation between people in diverse disciplines may be absolutely necessary to crack some problems. Instead of disconnected fragments of knowledge, we want to create a connecting web and a connected landscape of knowledge and information that can be generalized to engender understanding. With greater understanding comes the capacity for more learning though a better-focused approach to research and development. But as always; we must remember that no one avenue of research is all-inclusive, or is exclusively likely to yield results. While some may point to tremendous recent progress in String Theory, for example, it is mainly efforts to wed that discipline with the study of Twistors [24] which have yielded so many interesting new results.

We must move from vertical thinking, where we simply exert more effort with what we are already doing, to what Edward DeBono calls 'lateral thinking,' where different possibilities are explored side-by-side on an equal basis [25, 26]. In the first case, the vertical model; what usually happens is that information gathered becomes arranged in isolated 'silos' rather than existing in a form which is sharable. It would be better for cooperation to adopt the lateral model, but existing silos of knowledge are barriers to this and their existence presents unique problems. The ability to share the information gathered is essential to cooperation, but to an extent there need to be 'translators' or the translation of ideas into the terminology of the target audience. That is; mathematicians, scientists, and engineers, often use the same terms, but use some differently, therefore much care needs to be taken – so we know that our ideas are communicated transparently. Else, people could be in perfect agreement, and think that they disagree.

To an extent; the disparity in viewpoints we observe corresponds to the different outlooks of various portions of the brain. In my view, the left-brain's specialty is taking the watch apart, and noting the detail of all the pieces, where the right-brain is more skilled at assembling a watch and seeing how the pieces work together to create a functioning unit. It makes sense therefore, that if that entity is a research group; someone with a right-brained outlook might be required to see how it all fits together or how it can be made to function as a unit in service of the research. Someone who is overly deterministic in their world-view might miss the big picture, and could be a poor choice as one to lead a research group using this method, because lateral thinking calls for a more playful outlook overall and a greater scope of reasoning than if-then logic can provide. Playful exploration of possibilities and ideas has been the central theme of this paper, and DeBono's proven methods are an application of the same basic idea. Numerous researchers have settled on a similar picture, you see, and the reason is clearly that the most effective methods do not rule out innovation, before it happens, nor do they encourage us to try only those things that have already been yielded results. Instead; effective methods of research or development nurture possibilities until they can be effectively explored, and encourage them to be actualized, if that is believed worthwhile. This is the only road I see, which might lead to the cooperation and collaboration Professor 't Hooft is calling for, which is necessary to aid the progress of Physics.

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