Rubber Band Demonstration

Introducing Perceptual Control Theory

William T. Powers & Dag Forssell

Rubber Band Demonstration

introducing

Perceptual Control Theory "PCT"

July 17, 1993

This script and the accompanying video are designed to introduce and demonstrate the basic concept of PCT. The article *Perceptual Control: Management Insight for Problem Solving,* in the book: *Management and Leadership: Insight for Effective Practice,* contains another description of this *Rubber Band* demonstration. Please read the article to see how this demonstration shows one control system in action, supported by an entire hierarchy [see book, exhibit 17, for a conceptual outline] of control systems operating continuously. Enjoy the video!

Valencia, March 29, 1994

Dag Forssell

Video script

Introduction:

DAG: It is a challenge for any manager to guide and coordinate the activities of employees.

It is important for the prosperity of a company and the job security of the employees to meet that challenge in such a way that the productivity and quality of the company's programs, processes, products and services are appreciated in the marketplace.

If you can direct the employees while allowing them to direct themselves, you can create a win/win environment where it is a pleasure to work.

The purpose of our seminar is to introduce, teach and apply a new way to understand human behavior, which we call Perceptual Control Theory or PCT for short.

This new understanding shows you how to support your associates, employees, vendors, customers — indeed friends and family — so they can direct themselves well. — That's their win.

It also shows you how to create willing cooperation and teamwork, where everyone works on their own initiative on their part of the agreed task. — That's the company's win.

Continued...

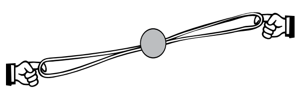
Objective: Phenomenon, demo's, language

DAG: Today, I am going to demonstrate the basics of PCT to you. The point of the demonstrations is to show the phenomenon of control, and to establish a way of talking about the elements of a control process and their relationships. This will give us a language to use when we deal with people. At the end we will see the implications of this for improved productivity and cooperation.

I'll be very detailed, so we lay a good foundation.

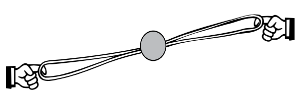
I'll use two rubber bands, tied together in a knot. A ping-pong ball makes the knot more visible.

Let us establish: Elements



Here's the experimenter's end of the rubber bands.
Here's the participant's end of the rubber bands.
You see the ball in the center of the rubber bands.

Effects

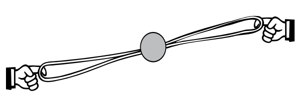


Stand facing the audience with one end of the rubber bands in each hand.

Notice the effect of the experimenter's action on the ball. The ball moves in exactly the same way, but by almost exactly half the amount. The effect of the participant's action on the ball is similar. You can both stretch it and move it up and down. Here you see the combined effect of both actions on the ball.

Affect what: Variables!

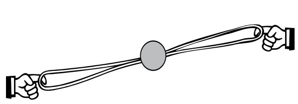
You can say that I am affecting the ball with my actions. But what is it about the ball that I'm affecting? It has the same color; it's always round. What I'm altering about the ball is its position, either up and down or side to side. It's only the position that is varying. The position can vary in two ways: up and down, or side-to-side.



So we can say that there are two independent *variables* involved. They are independent because you can change the up-down position without affecting the side-to-side position, and vice versa. If we know both variables, we know where the ball is in each of the two ways it can move, and that's all we care about right now.

Hand: Action, — Position, Variable.

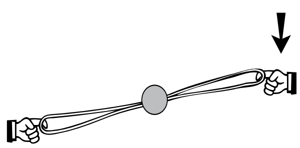
Now look at the hand holding the moving end. We say that this hand is carrying out an action. In this experiment, however, we're only interested in the action as it can affect the two variables that define the ball. We're interested in the *position* of the hand. Again, we have two independent variables. The hand can move up and down, or side to side. So we speak of the action that affects the ball in the same way we speak about the ball: in terms of variables.



At any moment the hand variables are set in a certain way. As a result, the ball variables are in a certain condition, the ball is in a certain position.

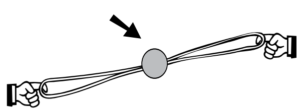
See difference: Influence - Influence: Learn about people:

All this elaborate analysis is meant to let us see something that's not usually understood very clearly: the difference between an influence and an influence. When you understand what that means, you'll already understand something important about human relationships.



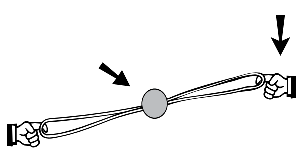
Hand: Influence on ball; Manager, Steering

Look at the moving hand. Obviously, when the hand moves, the ball moves. So would you say that the hand position is an influence on the ball's position? Isn't this like saying that the driver's steering efforts are an influence on the way the car moves, or the manager's instructions are an influence on the employee? This is one of the ways we use the word influence. We point to the cause of something else, and say that the cause is an influence on the something else. The moving hand is an influence on the position of the ball.



Ball: Influence by hand; Employee, Car

But now look at the ball. When the ball moves, you'd say that it's being influenced by something. You can focus on the effect of moving the hand, and call that effect the influence of the hand. Now, what do we mean by the influence? We mean the behavior of the ball that is caused by the hand. What is the influence of the hand on the ball? Just look at the ball and you can see it: the ball moves. There's the influence of the hand.



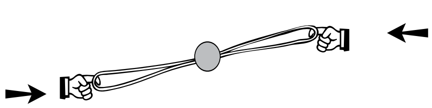
Two places:

So now we have an influence in two different places: in the thing that's causing the ball to move, and in the movements of the ball. We can say that the manager's strong personality is an influence, but we can look at how the employee's behavior changes, and say: That change in behavior is the influence that the manager had.

How and what influence people - variables

How do you influence people? Well, in the first place you don't influence people, you influence variables—you influence something ***about*** the person that is variable, like the person's behavior or attitude. You can't influence the person's height or age very much.

My Influence has influence? Action always have influence? Employees, spouse?



Ball remains stationary.

Assuming we realize that we're always talking about variables, we influence people by acting in a certain way on them. But does this influence necessarily have any influence? When you apply an action that is supposed to be an influence, is the other person's behavior always influenced? —Not by a long shot, and here's the reason.

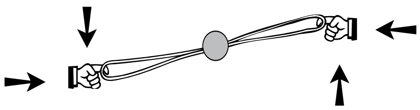
What happened?

Look, I'm applying an influence to the ball with my right hand, but its position isn't being influenced any more. The position of my right hand changes, but the position of the ball doesn't. Suddenly my influence on the ball has lost its influence. This is very mysterious. What has happened?

MARIA: Your other hand is moving the other way.

DAG: Can you be more specific?

MARIA: What do you mean?



DAG: Look closely. If the right hand moves to the right, the left hand moves to the left; if the right hand moves up, the left hand moves down.

See what happens if we do it in stages.

Equal and opposite:

Then explain that:

Each hand has a variable position, and each hand affects the variable position of the ball in each of the two possible ways. The only way for the ball ***not*** to move is for the variations in left-hand position to be exactly ***equal and opposite*** to the variations in the right-hand position. Only that will leave the ball in the same position, if the two rubber bands are identical. The *influences* of the two hands on the ball are equal and opposite, with the result that there is no influence on the ball.

Think of this

So the next time you try to get a vendor or an employee or a customer to behave in a certain way, you will think of this, won't you? What you say or do may be an influence on the behavior of the other person, but it may not have any influence. Why not? Because there may be another equal and opposite influence coming from somewhere.

Find out Volunteer

Now we're going to find out where the most important equal and opposite influence comes from. May I have a volunteer, please?

Thanks, Liz. Please read and follow the instruction on this card.

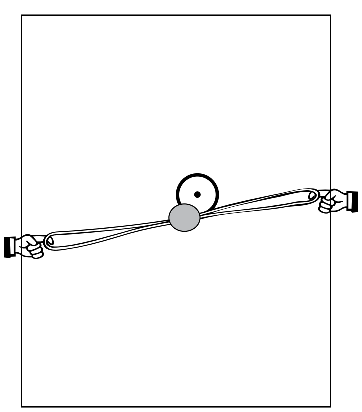
> Please keep the ball as exactly over the center of the circle as you can.

Liz Instruction

← *Now you turn to the easel with the paper on it, and draw a target circle.*

← Liz, let's keep our hands lightly touching the paper.

Apply disturbances very slowly and smoothly. Adjust your speed so the volunteer can keep the ball over the circle very accurately. Don't let transients occur; they're confusing at first.



Influence: See it? Gone! Why?

Now watch. I pull back, using the influence I have on the ball to make the ball move. I move my hand up, influencing the ball to move up. I move down, around in a circle, all different ways. And you can see the influence on the ball that my hand is having, right?

Right???

KARIN: I don't see much influence.

DAG: So it is wrong!! So even though I'm varying my hand position up and down and side to side, the ball isn't varying that way. Why isn't my influence having any influence?

KARIN: Because Liz is moving her hand the other way.

DAG: Yes. I'm applying an influence to the ball, but the ball isn't moving because Liz is applying an equal and opposite influence to the same ball. It's just the same as when I had hold of both ends of the rubber bands, but now Liz is playing the part of my other hand.

Cause?

Why do you think Liz is doing that?

DAVID: Because you asked her to.

DAG: Yes, but what exactly do you think I asked her to do? What would you guess the exact instructions were on the card?

KARIN: Oppose my movement?

MARIA: Mirror my hand?

DAVID: Do the opposite of what I do.

DAG: Liz, what was written on that card.

LIZ: Please keep the ball as exactly over the center of the circle as you can.

How: Explain instructions:

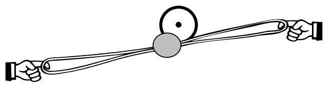
DAG: I didn't tell Liz how to move her hand. I asked her to produce acertain effect on the ball, and she evidently agreed to try. And she succeeded very well.

But ***how*** did she succeed? What was she doing, inside, that created the result you saw? Now we're looking for something beside just a description of what we all could see happening. We're asking how Liz could be organized so she was able to do what you saw her doing. We're looking for an ***explanation*** of what we saw.

How does Liz work?

You've all heard explanations of human behavior, according to one theory or another. You've probably found some explanations more convincing than others. I'd like to find out now what sort of explanation you think would apply to this little experiment. How do you think Liz works, which would explain what she was doing? For example, how many of you think that Liz could keep the ball over the circle with her eyes closed?

(Get a show of hands).



(Liz closes her eyes)

Demo: close eyes

Nobody thinks you could do it, Liz. Close your eyes, and carefully follow this instruction. Listen carefully: keep the ball exactly over the circle.

ALL: Laughter

DAG: Well, it's pretty obvious that Liz can't follow the instructions with her eyes closed. We have made a great discovery: when Liz closes her eyes, she becomes deaf.

See hand, dry marker

All right, if that's not it, what do we know now? Why did Liz have to see what was going on?

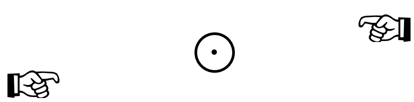
MARIA: To see what she was doing.

DAG: Let's try to get very specific. What exactly did Liz have to see in order to do what she did?

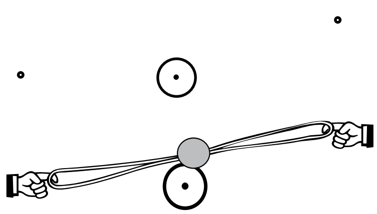
DAVID: Your hand?

MARIA: The ball?

KARIN: The rubber bands?



DAG: Well, let's test a couple of these ideas. If Liz had to see my hand, then it wouldn't make any difference if she couldn't see the ball, right? So we can just dispense with the rubber bands and the ball, and Liz can move her hand the way she thinks she needs to move it when I move my hand. When I say freeze, Liz, just rest your hand on the paper and hold it there. I'll do the same. Here we go.



Both have dry markers, to mark the position

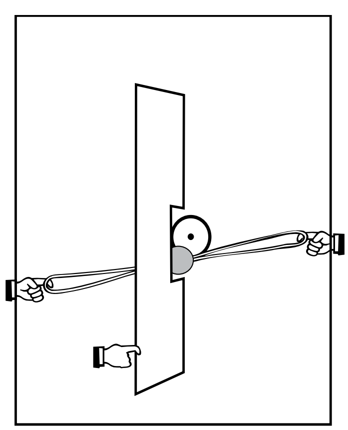
Freeze. Now with my other hand I connect the rubber bands the way they were, and let's see where the ball is.

This is one reason for making sure that Liz can control very easily and accurately.

Well, not too bad. Are you satisfied with that, Liz? If not, go ahead and put your hand where you think it should be.

Liz corrects remaining error.

See ball



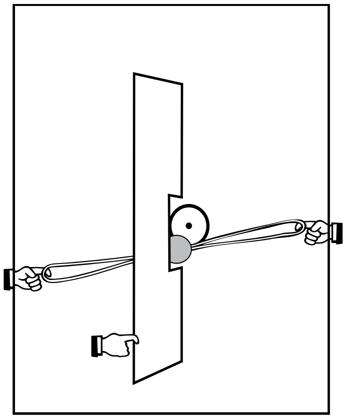
Use slow large disturbances.

Now, Maria said that Liz was looking at the ball. Suppose that's true: she can see the ball, but not my hand. I'll hold up this piece of ← cardboard with a notch in it, and Liz, you position yourself so you can see the ball but not my hand or arm. Ready? Here we go.

All right, we have evidence now. What's your conclusion?

KARIN: It works much better when you see the ball.

MARIA: I agree, but Liz came close when she looked at the hand.



DAG: Well, then let's ask. Liz, while you're keeping the ball over the circle, are you looking at my hand or at the ball?

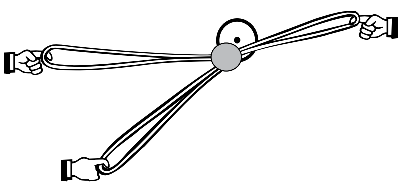
LIZ: The ball.

DAG: Liz has served us well, but it's time to see if he's the only person in the world who can do this task. Thank you, Liz. Can I have another volunteer, please.

David See ball

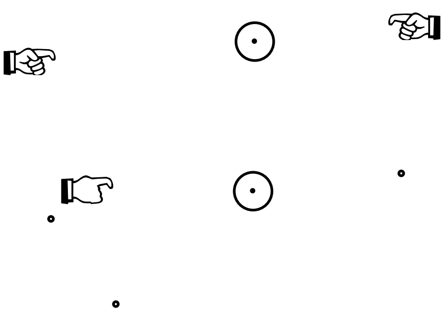
David, thanks. Just a quick check: keep the ball exactly over the circle, while I hold up the cardboard — be sure you can't see my hand or arm.

Good, you work the same way Liz does. Would you like to try it with your eyes closed? —No, I didn't think so.



(Slow motions, good control).

Maria thought Liz did OK when she was watching the hand. With this simple prop you are only fighting one influence. It is easy to visualize where the ball is. David, will you help me repeat the experiment where you have to fight two influences. You can think of it as driving. Liz was fighting curves. You get to fight both curves and crosswind. First, just keep the ball over the circle. Here we go.



DAG: OK. Now let's try it without the bands. When I say freeze, David, just rest your hand on the paper and hold it there, just like Liz did. Here we go.

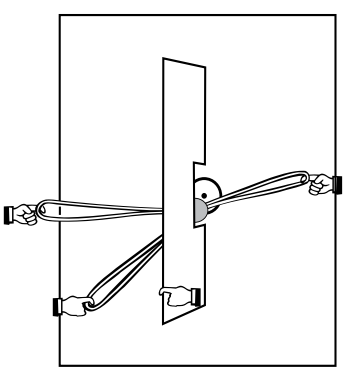
Freeze. Now let's see where the ball is.

(Error larger than before).

Now, go ahead and put your hand where you think it should be.

David corrects remaining error.

David, will you help me by holding up this cardboard with your other hand and position yourself so you can see the ball but not my arm. Ready? Here we go.



All right, we have more evidence now. What's your conclusion this time, Maria?

MARIA: It makes a big difference what you look at.

See ball sufficient?

DAG: Can we agree now that watching the ball is sufficient? In other words, David doesn't ***have*** to see my hand, and it probably wouldn't make much difference if he could because he could hardly keep the ball centered any better.

David, why don't you sit down for a little while, because I want to draw a diagram before we go on.

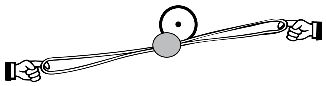


Diagram:

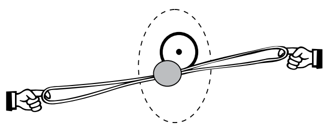
← *Draw the rubber bands and ball with the target circle a little off.*

We've established that Liz and David look at the ball during this task. David, did you also need to see where the target is?

DAVID: Yes.

DAG: Liz, you too?

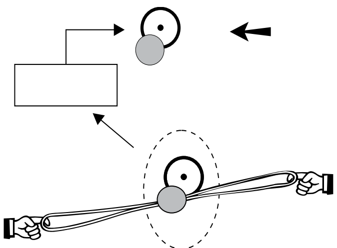
LIZ: Yes.



DAG: So they were looking at something in this region:

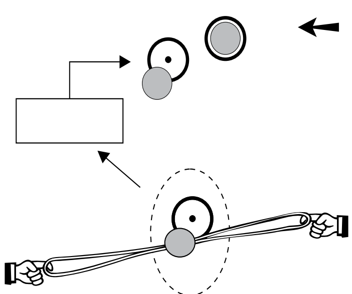
← *Draw a circle around target circle and ball.*

Seeing picture:



Now what does 'seeing' mean? We see with our eyes, of course, but what gets into our eyes has to get into the brain, too, before any perception happens. So let's draw a box up here, with an arrow representing light rays coming into the box, and an arrow coming out that represents what the brain knows by way of these light-waves. Right at the end of the arrow coming out of the box, I'll draw what ← the brain would be seeing right now, based on how the diagram looks. Here's the ball, and here, away from it a bit, is the circle.

'What it should look like' – picture:



DAG: David or Liz: If this is what you saw, what would you try to do?

DAVID: Get the ball over the circle.

DAG: How would I draw a picture of that?

DAVID: Draw the ball inside the circle.

DAG: ← Like this?

DAG: So here we have a picture of how the ball and the circle actually ← look right now *[indicate perception]*, and here we have a picture of ← — what? —anyone?

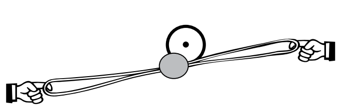
LIZ: How they are supposed to look.

DAG: ← How did you know? Would it be accurate to say that this *[reference picture]* is how you wanted them to look?

DAVID: Yes.

DAG: Is this how they always looked?

DAVID: No.



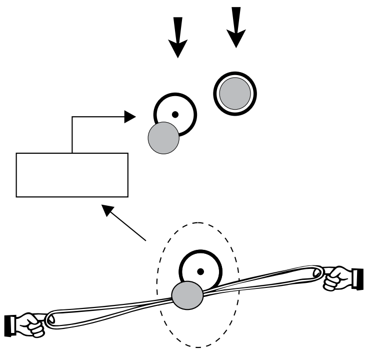
DAG: Well then, how did you know how they were supposed to look? ← Before you answer, David, will you come up here again and do a short run with me?

Now, how did you want the ball and circle to look?

Rapidly: The ball wobbles.

DAVID: ← *(Points to picture).* Like this.

DAG: Most of the time, how ***did*** it look?



DAVID: *(Points to picture of perception).* Like this.

DAG: Thank you. OK, you knew it should look like this? *[Point to reference picture].* And most of the time it actually looked more like this? *[Point to perceptual picture].* Good. Well, if most of the time it looked like this *[perception]*, how did you know about this? *[Point to reference picture].*

How do you know? - Drive

Let's switch to another example for a moment. Most of you drive cars. When you are going along a straight road, you steer the car to keep in its lane. What are you seeing out the windshield in front of you?

KARIN: The road and other cars.

DAG: Now consider: how do you know where the car is in its lane?

MARIA: You just look.

DAG: And finally, how do you know where it ***should be*** in its lane and in relation to other cars?

Where is knowledge? Head!

All this is building up to a point that a lot of you may have seen by now. The remaining question is, ***where*** is this knowledge of the way the car and road, or the ball and circle, should look?

LIZ: In your head.

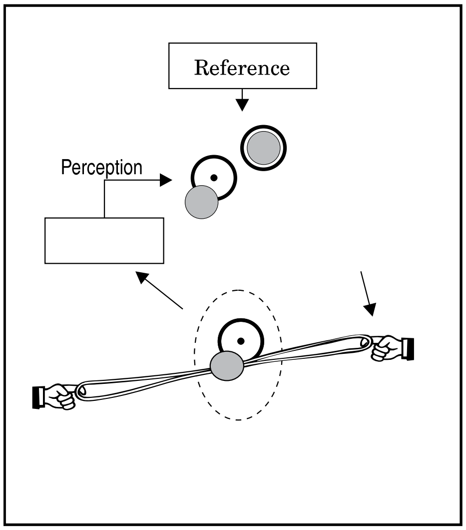
DAG: In your head. Can all of you imagine a ball centered in the circle, right now? —Can all of you imagine the way the car and road look when you're in the right position on the road? And where is that imaginary picture, right now? —In your head — or at least, not anywhere in the room outside of you. Even if you don't actually see an imaginary image, there's knowledge, somehow, of how the scene should look when it's right. Right? —

Getting ready to understand theory

Now, you're ready to understand the theory of human behavior that's behind this presentation. Just a few more steps.

Terminology: Perception:

DAG: First, let's start using some consistent terminology. This arrow in the brain, up here, that shows how the ball and circle actually look right now, we'll call the perception. Notice that we don't call the actual ball and circle down here, the real ones, the perception. The perception is what the brain, up here, knows about the world, down here.



Reference perception:

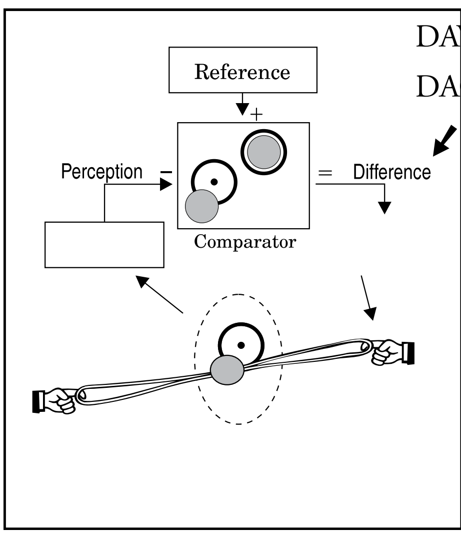
If the picture of the actual situation is the perception, then what can we call this other *[reference]* picture? It's not a perception of the actual ball and circle. It's an imagined perception. We judge the perception of the actual ball and circle with reference to this other picture. It just sits there unchanging, telling us how the actual perception should look, not how it does look. So let's call this other picture the reference perception. Or we could say the reference condition of the perception, or just the reference condition. The key word is reference, because it's with reference to this *[reference picture]* that we judge this *[perception]*. Of course, it comes from somewhere in the brain, so we draw a box here.

What call process: Comparison

Now I ask you: is this *[perception]* the same as this? *[reference]*. How do you know that? What would you call the process you carry out in order to decide that they're not the same?

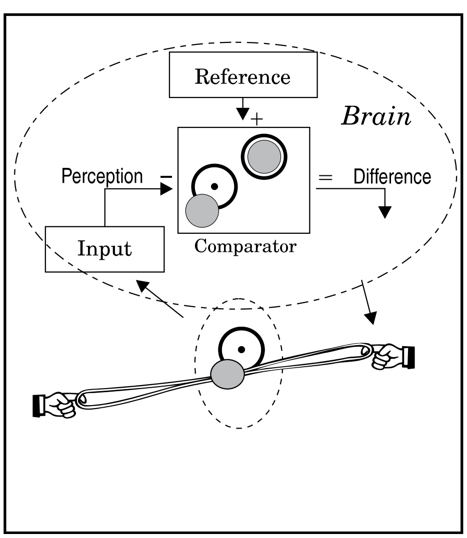
MARIA: Subtraction.

DAVID: Comparison.



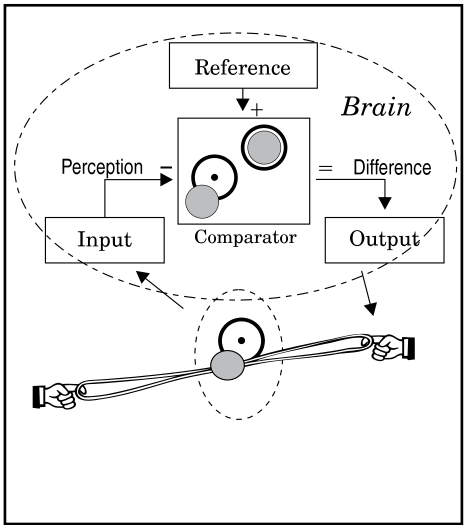
DAG: That's interesting. We call it comparison, and when we draw models, we draw a box right here, which receives information from the perception and from the reference and compares them. We call it a comparator. And what comes out of the comparator? Information about the difference between the perception and the reference. If there's no difference, no information comes out. If the perception is different, this arrow carries just the information about the difference. We can call this arrow a difference signal — in control theory it's called an error signal, and you can use that term too as long as you understand exactly what it means. It doesn't mean mistake or blunder, it just means that there's a difference. If there's any amount of error signal up here, we know that the real ball, down here, is not in the same position as the circle —or at least isn't perceived that way.

Maria, you were right about subtraction. Subtraction is how you compare in math. By subtracting the perception from the reference, we get the difference.



Input function:

While we're at it, let's identify this other box down here. It's called an input function or a perceptual function. It receives light-rays or other physical information about the world, and converts it into some sort of representation in the brain. It creates a perception, or as we sometimes say a perceptual signal, that continuously indicates the state of the outside world. Right now, your brains contain some perceptual signals that indicate how my words are sounding and how I look as I stand up here. Obviously, everything in this region of the diagram is in the brain [draw big circle] and the rest is outside the brain.



Review signals

⟵ So way down here we have the actual circle and ball. Information comes from them into this perceptual function, creating this perceptual signal that always indicates the relationship of the circle and ball. Up here we have another signal, the reference perception or condition that's showing how the perception ***should*** be. And here is the comparator receiving both of those signals, comparing them, and spitting out a signal that represents how much difference there is — how far from the reference condition the perception is, and in what direction. These so-called signals are simply currents flowing through nerve fibers in the brain. But we don't have to worry about neurology here; this is about organization.

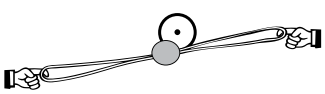
⟵ Now if the perception looks like this, and the reference looks like ⟵ this, what should Liz or David do? Obviously, move the arm to ⟵ the right and up so that the ball goes this way, toward the target. It would work equally well if the arm could make the target move the other way, toward the ball. And where is the information that tells ⟵ which way to start moving? Right here, in the error signal coming out of the comparator.

Output function:

All we have to do is hook up this difference or error signal to an ⟵ output function right here, which tells David's muscles to move, to take action, in the right way, and the hand will automatically affect the ball, and keep affecting it until there's no more difference signal to tell the hand to move some more. Let's watch it happen.

⟵ David, if you'll help me again —

Stop motion ***Looks like: Stimulus-response***

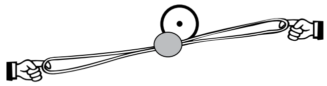


Center the ball. Thank you. Now we'll do this a little differently, in ⟵ stop-motion. First, close your eyes. Now open your eyes and make what you see look right. Close your eyes again *[move in different direction]*. Open again. Close again. Open again [etc.]. Thank you. Please wait.

By stopping the motion, we can see what's going on. Each time David opens his eyes, he sees a different picture of the ball and circle. The reference condition is the same, so the comparator puts out a different error signal each time. This results in a different motion of the hand each time, and it's always in the right direction to make the perception move toward the reference condition.

(Point to the right places on the diagram as you talk).

When we stop the motion like that, we see what looks like a series of stimuli followed by responses. But when we do it in the natural way ...



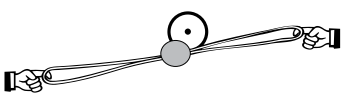
⟵ David, one more time, please, with eyes open *(Smooth)*

. . . you can see that there are no stimuli and responses. The difference or error is never allowed to get very big, unless I start moving this end of the rubber bands too fast. In fact, David is acting continuously to keep that error or difference signal from ever getting very large. By doing that, he is keeping the perception of the ball and circle very close to this reference picture. It takes only a very tiny error to make David's arm start moving to correct it; the effect of the movement is always just right to keep the error small.

Car in ditch?

This is how you drive a car, isn't it? You don't wait for the wind or a tilt in the road to put you in the wrong lane, and then steer back. As soon as you can detect ***any*** difference between where you perceive the car to be and where you want it to be, you alter your steering efforts just enough to prevent that change from getting any bigger. So your car hardly wanders at all. At least that's how I hope you drive. These little corrections are quite automatic. You don't have to know about these signals in the brain or how they're hooked up. All you have to do is pick a reference condition. This little circuit here will then make sure that what you perceive matches what you intend to perceive. This little circuit is called a negative feedback control system. Negative because of this minus sign. This reference signal is where you put your intention in.

Slow motion:



⟵One last look. David, I'd like you to go into slow motion. Do everything just the same, but slow down your actions as if you have to push your arm through heavy syrup. Let's try it. I pull back on my end, and you slowly bring the ball back to the circle. You don't have to wait for my motion to finish; you can start acting right away, but make your action very slow.

If you pay close attention to the video, you will notice a flaw in Dag's performance right here. Dag, too, as part of the demonstration, wanted the ball eventually to end up in the circle, got impatient, and ended up helping David get it there. Therefore, Dag did not properly play his role as a pure disturbance.

Errors small!

Now you can see how disturbing the ball creates a little error, which starts the arm moving the right way. After a while the error is gone again. While my arm is moving, there's a continuous error, which is keeping his arm moving the other way; when my arm stops, he catches up and the error disappears. Thanks, David.

That was like seeing a slow-motion film of a control system in action. There's always a little error, a little lag, but not very much. The action is always pretty much equal and opposite to the disturbance, and the error is always pretty close to zero.

Review: Now you can understand mirroring, prevention, what mattered.

Think back now to where we started. Liz got up here and moved her end of the rubber bands around, and you saw what she was doing, but did you understand what you were looking at? Now we have a model to explain what's happening. YOU can see why

David's or Liz's hand seemed to be mirroring my motions, as if imitating them. YOU can see why Liz acted to prevent me from having any influence on the position of the ball. YOU can see that what mattered was not how my arm moved, but how the ball moved. Liz and David's actions were controlling the ball, not just reacting to my arm movements. They didn't even need to see my arm or what it was doing to the rubber bands. All they needed was to see where the ball was, and know where they wanted it to be. That explains everything you saw.

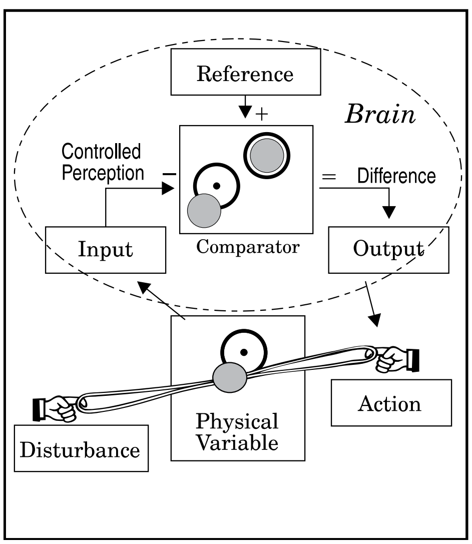
Engineers:

When engineers work with systems organized like the one in the diagram, they bring all sorts of mathematical language into it. But they're talking about the same system you see here, behaving just as you saw it behave, organized exactly as you see it organized in this diagram. A closed circle of ***simultaneous*** cause and effect. Perception, comparison, and error driving an output — although they wouldn't talk about perceptions.

Now you understand the essence of this sort of system in just the way an engineer might understand it.

Remaining terms:

The last thing we have to do is clarify a few terms, and then we will be armed and ready to tackle the application of this concept to human behavior in the areas that interest you.



Disturbance:

⟵ At my end of the rubber bands we have something we will refer to as the disturbance. We call the position of my end of the rubber bands the disturbance because it disturbs the ball, or would if there were no other influences acting on the ball.

Action:

⟵ At the other end, we have the person's action. The term action means just what the person's muscles are directly causing to happen, positioning the hand. We can talk about the action without talking about any other effects it might have. The action is also an influence on the ball, but as you have seen, the behavior of the ball isn't the same as the action itself.

Physical variable:

⟵ And in the middle we have the physical variable. In this case the physical variable is the position of the ball relative to the circle. We call it physical because it is outside the brain in the physical world and all we know about it are perceptions. We call it a variable because it is capable of varying. Sure, the other things are variables too, but we focus on this one because it is important. This is what the reference perception is about, and what we perceive.

Controlled perception:

The actions affect the physical variable until the perception of it agrees with the reference perception, and the actions vary in whatever way is needed to keep the perception as specified. That's what we mean by control. You can see that what is being controlled is the perception. The perception is what we compare with the reference, and that comparison is the essence of control.

Summary: Environment/brain. Questions:

So in the environment outside the brain, we can see a disturbance, a physical variable, and an action that is producing the control of the perception.

In our model of what goes on inside the brain, we can see a perception that represents the physical variable, a reference condition or signal that represents the intended state of this perception, and an error or difference signal that drives the action. Put all these elements together, and they add up to an explanation of the behavior you have been seeing. Any comments or questions?

LIZ: This is interesting.

KARIN: Does this explain motivation?

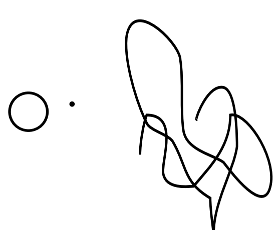
DAG: Yes, it does. It also tells you a lot about empowerment, conflict, cooperation, teamwork, planning and leadership. — In other words why people do what they do and how it affects human relationships.

Little Johnny & Sally story.

Karin Behavior:

OK. Now let's talk about what behavior is. I need another volunteer just for a couple of minutes. Karin. Good, come on up. You will see that PCT gives a person a lot of confidence. It works with any randomly-selected person.

What it is, squiggly line:



DAG: Here's a marker. Hold it against the paper while you move your end of the rubber band, so it leaves a trace. Keep the ball exactly over the circle. Right. Now just keep it there for a while.

Put in a slow but broad pattern of disturbances.

Thank you — that's all. Suppose that someone just now came into this room, and heard me say: "This trace was created by Karin's hand in the experiment you just saw." What might that person conclude about Karin's behavior?

ALL: Laughter

You can't tell:

DAG: You can't say that Karin's behavior didn't produce this wavering and wandering trace. It did. But is that what Karin was doing? Was she really just making this squiggle on the paper? PCT teaches us that: "You can't tell what a person is doing just by looking at what the person is doing." Here's a beautiful example of that. What Karin did was to move the dry marker around and leave this trace. But what she was ***really*** doing was keeping the ball over the circle. You, who know about the controlled variable that Karin was concerned with, understand that. But the person who came in late didn't see the controlled variable. The only evidence left is the record of Karin's actions, which tells us exactly nothing about what Karin was controlling by means of those actions.

We look at actions. What we can't see.....

So you can't tell what a person is controlling just by looking at that person's actions. This is a profoundly revolutionary idea. In most ordinary aspects of life, we look at the people around us and we think we can see what they are doing. We look at their behavior. But what are we really seeing? We are seeing their actions. We are not seeing the variables that are being perceived by those people, and being controlled so that the perception is kept near some reference condition.

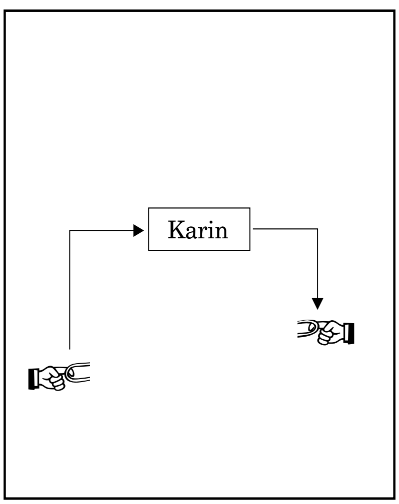
Only person knows perception, reference!!!!!!

Only the person we're looking at knows what perceptions exist, and what state of those perceptions that person would prefer to experience. Only that person can see the relevance of the action to maintaining control over a particular perception.

Observer can't see purpose!

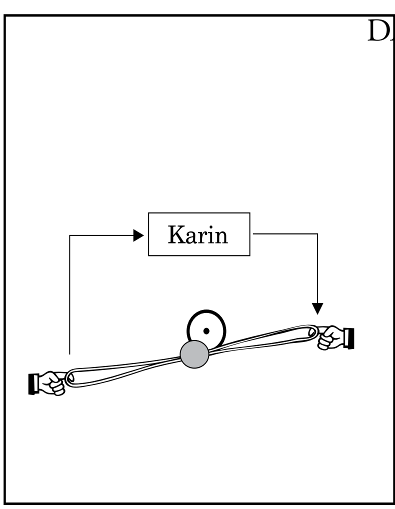
We, observing from the outside, can't see the purpose of the actions.

S-R diagram, Cardboard Imagine repeat with cardboard...



Imagine that we went through another session with this demonstration, but held up a big piece of cardboard so the audience couldn't see the ball and circle. You could see my hand on one side, and Karin's hand on the other side, and you could see them moving, but that's all. Wouldn't it seem that Karin's hand movements were being caused by mine? It would look as though Karin was watching my hand movements, and responding with symmetrical hand movements of her own. If you had to draw a diagram of what was going on, you'd draw it like this:

DAG: The box is Karin. The movement of my end of the rubber band is sensed by Karin, and this stimulates her to move her end of the rubber bands. We have a nice simple cause-effect diagram, and Karin is just a link between the cause and the effect.



If grind, what will happen when cardboard removed...

If you ***grind*** that concept into your mind and ***really*** come to believe in it, what will happen when we take the piece of cardboard away? You'll see that the stimulus not only makes Karin's hand move, but tends to make the ball move because of the connecting rubber band. You'll see that Karin's hand movement also tends to make the ball move, but the other way. What an odd coincidence! The ball moves hardly at all.

Reinforcement

Now, if keeping the ball directly over the circle were vital to Karin's health and safety, you might begin to wonder how the response knows that it should cause Karin to move her hand in just the way that's in her own best interests. You'd try to find an explanation. You might propose that moving the ball towards the circle was reinforcing to Karin's conditioning. Whenever Karin didn't move the right way, the reinforcement wouldn't happen, so that response would die out. Only the response to the stimulus that happened to bring the ball back over the circle would be reinforced, so that response would eventually be the only one left.

Explanations must fit convictions

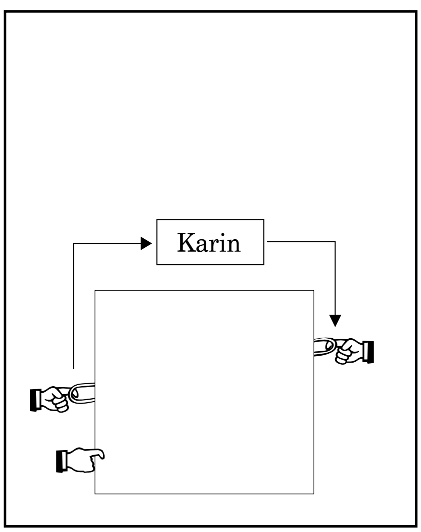
You can see how it goes. Once you get a model firmly in mind and decide to believe it, all of your explanations from then on have to fit that model, even though they leave you with other mysteries. Just why should a ball being over a circle be reinforcing to Karin? You can't answer that question. All you know is that this explanation seems to work.

YOU compare: PCT / S-R, Reinforcement

Now you understand the PCT explanation of what we've seen. You can compare the PCT explanation with the one we've just been through. While you're comparing, consider this:

Consider: Scientists believe, you learn in school.

The reinforcement explanation and the cause-effect model are the ones in which nearly every scientific psychologist has believed for most of this century. It is the one you learned in school. It's woven into our language and beliefs in ways that are so taken for granted, they're almost unconscious.



Incentives? Causes?

Have you ever thought that by applying incentives to someone, you can get that person to behave differently? Like a parent offering candy to a child as a reward for good behavior. Have you ever explained your own behavior by pointing to something in your environment, and saying that's why I did it? Like the phone rings — you answer!

Great minds - cardboard

Long ago, before anyone in this room was born, the great minds of psychology held up a big piece of cardboard. They said, "Never mind what's behind this piece of cardboard. Just look at this end of the rubber bands and that end of the rubber bands. Isn't it obvious that movements over here are causing Karin to move her hand over there? You don't need to talk about purposes and intentions and desires and wants and wishes."

Observe cause-effect —> can predict & control.

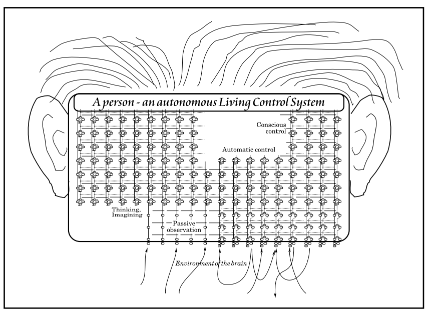
All you need to do is observe what causes what. Then you'll be able to predict and control human behavior.

Doesn't work. People have wants.

Everyone who has been a parent or a manager, has tried to sell something or organize a team knows what is wrong with that. People are not simply boxes with inputs and outputs, devices that can be made to act in certain ways by applying the appropriate stimuli. People have goals and desires and wishes and purposes and hopes and intentions. If you ignore them, you will probably get into conflict.

People ***are*** control systems. Some people realize this without having any formal understanding.

I am sure you appreciate that a person is not ***one*** control system, although you have seen that a person can function like one. In experiments with Perceptual Control Theory, we focus on one control function at a time. But some of the exciting implications come from viewing people as a system of control systems. Here is one suggestion of how that might look:



← *Overhead slide of "portrait."* — *A sequence in the video.*

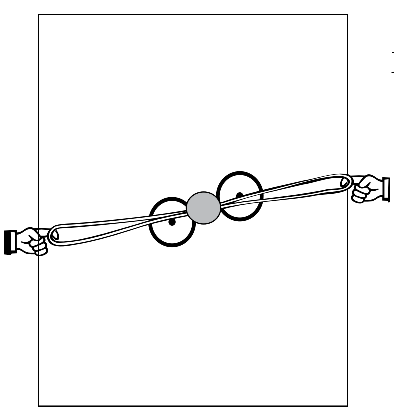
This portrays a hierarchical extension of PCT. It offers suggestions about where the reference signals we've been talking about come from, how the mind may be organized, how we think, observe, stand without even thinking about it and keep the ball over the circle with full attention. We explain it in detail in our seminar. You can take advantage of these ideas to improve your personal relationships, on and off the job. For instance, have any of you ever wondered why people change their minds?

DAVID: I have. As a manager, I find it hard to get people to make commitments and then keep them. I have to talk to some people over and over again, and that is a waste of time.

DAG: You are not the only one who is frustrated. With a system of control systems we can explain internal conflict and how conflict between control systems explains some of these things.

Conflict.

DAG: For now, let's do a demonstration of simple conflict between two control systems. I'll need two volunteers.



← Liz, Maria. You are good sports. Liz, will you please take this end of the rubber bands and take the target on your side as your own.
← Maria, will you do the same on the other side. Here we go.

Liz and Maria pull way apart. *Laughter.*

← Whoa, what is happening. Let's get away from those rubber bands
← before they snap. Here is some string instead. Try again.

Pulling hard. Grunts.

Liz, are you satisfied?

LIZ: I am doing all right.

DAG: Maria, how about you?

MARIA: I can't make it, no matter how hard I try.

DAG: There you have it. We can leave Liz and Maria, and they will struggle until they are exhausted. Let's not do that. Thank you both. We can learn several things from this simple demonstration.

Conflict is exhausting. One party may be satisfied, but not both. The reason for the conflict is that both parties try to control the same variable, using different references. You can see what it takes to resolve conflict, right?

MARIA: Liz could change from her target to mine. I have a better target.

Laughter

DAG: You are so right. Let's do that, Liz, and try again. This time, I'll ask ← each of you to look at the ball and target from your own perspective. Be sure to visually align the ball and the circle, not imagine what it looks like from the front, but see it from your own angle. Here are the rubber bands.

Same result as before. Laughter.

Thank you ladies. Any conclusions?

KARIN: There is still conflict.

DAG: What can we do about that? How about asking Liz to look at the problem from Maria's point of view as well as adopt the same reference? The obvious question is how to accomplish that in a win/win fashion. We all know from experience that this is not always easy or even possible. Can you begin to see that the PCT explanation allows us to understand what is going on and can tell us what it takes to resolve the conflict between Liz and Maria?

PCT missing piece in puzzle

PCT is the missing piece in the management puzzle. It gives you a theory of how humans work that explains every variation of behavior. When you have internalized this model, you may not need a whole variety of management programs. I hope this short demonstration has given you a feeling for how PCT can change our approach to management, and to getting along with people in general.

Rubber Band Demonstration Outline
By William T. Powers

Personal e-mail from Bill Powers to Dag Forssell April 3, 1993.

The point of this e-mail was to improve upon the rubber band demonstration featured in the "PCT Supports TQM" video tape, which was recorded less than a month earlier.

Hello, Dag —

I will work with you to make this demo section of the talk an effective teaching tool. How effective it is will depend on how well the audience understands it, and how well they can relate the principles embodied in the demo to other situations.

The point of the demos is twofold. First, you're just demonstrating a phenomenon of control, which is interesting in its own right, as you have found. Second, you're establishing a way of talking about the elements of and relationships in a control process, so you can use this way of talking later and remind people of what they learned through reminding them of their experiences with the rubber bands. The more clearly you establish what you're talking about in the beginning, the more easily the audience will understand what comes next. I'm going to lay out a strategy for doing this in a period of about an hour. The following segment may seem long and detailed to you. You may worry that the audience will wonder what this is all about, but don't worry. They will be interested because they are learning something.

The first thing you must do is carefully show the audience the physical elements of the rubber bands, so they will know what is important to notice.

a. The experimenter's end of the rubber bands.
b. The participant's end of the rubber bands.
c. The ball in the center of the rubber bands.
e. The effect of the experimenter's action on the ball.
f. The effect of the participant's action on the ball.
g. The combined effect of both actions on the ball.

You can do this part alone. You can stand facing the audience with one end of the rubber bands in each hand. Hold one end of the rubber bands still and move the other end, being sure you point out that you can both stretch it and move it up and down. Show that when you move your hand by a certain amount, the ball moves in exactly the same way, but by almost exactly half the amount. Show that this is true when you move either end, holding the other end still. Then return to holding one end still while you move the other end.

Now talk briefly about variables. You can say that you're affecting the ball with your actions. But what is it about the ball that you're affecting? It always has the same color; it's always round; its price is still whatever it was. What you're altering about the ball is its position, either up and down or side to side (illustrating as you speak with the appropriate move). It's only the position that is varying. The position can vary in two ways: up and down, or side-to-side.

Here's an example of how the spiel might go:

"So we can say that there are two independent *variables* involved. They are independent because you can change the up-down position without affecting the side-to-side position, and vice versa (illustrating as you speak). So we are really talking about two variables here. If we know both variables, the up-down position and the side-to-side position, we know where the ball is in each of the two ways it can move, and that's all we care about right now.

"Now look at the hand holding the movable end. We say that this hand is carrying out an action. In this experiment, however, we're only interested in the action as it can affect the two variables that define the ball. We're interested in the *position* of the hand. This is a variable, too, and in fact it's two variables. The hand can move up and down, or side to side [illustrating as you speak]. So we speak of the action that affects the ball in the same way we speak about the ball: in terms of variables. At any moment the hand variables are set in a certain way. As a result, the ball variables are in a certain condition, the ball is in a certain position.

"All this elaborate analysis is meant to let us see something that's not usually understood very clearly: the difference between an influence and an influence. When you understand what that means, you'll already understand something important about human relationships.

"Look at the moving hand. Obviously, when the hand moves, the ball moves. So would you say that the hand position is an influence on the ball's position? Isn't this like saying that the driver's steering efforts are an influence on the way the car moves, or the teacher's personality is an influence on the students? This is one of the ways we use the word "influence." We point at the cause of something else, and say that the cause is an influence on the something else. The moving hand is an influence on the position of the ball.

"But now look at the ball. When the ball moves, you would say that it's being influenced by something. You can focus on the effect of moving the hand, and call that effect the influence of the hand. What do we now mean by the influence? We mean the behavior of the ball that is caused by the hand. What is the influence of the hand on the ball? Just look at the ball and you can see it: the ball moves. There is the influence of the hand.

"So now we have an influence in two different places: in the thing that's causing the ball to move, and in the movements of the ball. We can say that the teacher's strong personality is an influence, but we can look at how the student's behavior changes, and say "That change in behavior is the influence that the teacher had."

"How do you influence people? Well, in the first place you don't influence people, you influence variables — you influence something ABOUT the person that is variable, like the person's behavior or attitude toward you. You can't influence the person's height or age very much.

"Assuming we realize that we're always talking about variables, we influence people by acting in a certain way on them. But does this influence necessarily have any influence? When you apply an action that is supposed to be an influence, is the other person's behavior always influenced? Not by a long shot, and here's the reason." [Now you move both ends of the rubber band around so the ball remains stationary.]

"Look, I'm applying an influence to the ball with my right hand, but its position isn't being influenced any more. The position of my right hand changes, but the position of the ball doesn't. Suddenly my influence on the ball has lost its influence. This is very mysterious. What has happened?"

The audience, of course, can see you moving your other hand. Ask them to explain why your right hand has lost its influence on the ball. Tell them to go ahead and say why, even if it's perfectly obvious. Say it out loud, put it into words. But pin them down to an exact statement. Sure, it's because your other hand is moving the other way. But show them that if your right hand moves to the right, the left hand moves to the left; if the right hand moves up, the left hand moves down. Show them again what would happen if the left hand didn't move (the ball moves to the right), and then what happens when the left hand moves (the ball moves back to the left).

Then explain that each hand has a variable position, and each hand affects the variable position of the ball in each of the two possible ways. The only way for the ball NOT to move is for the variations in left-hand position to be exactly EQUAL AND OPPOSITE to the variations in the right-hand position. Only that will leave the ball in the same position, if the two rubber bands are identical. The *influences* of the two hands on the ball are equal and opposite, with the result that there is no influence on the ball.

"So the next time you try to get a vendor or an employee or a customer to behave in a certain way, you will think of this, won't you? What you say or do may be an influence on the behavior of the other person, but it may not have any influence. Why not? Because there may be another equal and opposite influence coming from somewhere.

"Now we're going to find out where the most important equal and opposite influence comes from. May I have a volunteer from the audience, please?"

Now you turn to the easel with the paper on it, and draw a target circle, and take the volunteer aside and whisper the simple instruction. You can explain out loud that you and the volunteer are going to keep your hands lightly touching the paper. Assume the position.

When you apply disturbances, apply them very slowly and smoothly. Adjust your speed so the volunteer can keep the ball over the circle very accurately. Don't let transients occur; they're confusing at first.

"Now watch. I pull back, using the influence I have on the ball to make the ball move. I move my hand up, influencing the ball to move up. I move down, around in a circle, all different ways. And you can see the influence on the ball that my hand is having, right?" [Turn to the audience and raise your eyebrows and ask, inviting an answer, "Right?" Get the audience to point out that you're not having much influence.]

"Wrong. So even though I'm varying my hand position up and down and side to side, the ball isn't varying that way. Why isn't my influence having any influence?" [Audience, even if you have to drag it out of them: "because Jim is moving his hand the other way."]

"Yes. I'm applying an influence to the ball, but the ball isn't moving because Jim is applying an equal and opposite influence to the same ball. It's just the same as when I had hold of both ends of the rubber bands, but now Jim is playing the part of my other hand."

"Why do you think Jim is doing that? [Because you told him to]. Yes, but what exactly do you think I told him to do? What would you guess the exact instructions were?"

Now there is a period of discussion while people volunteer guesses. Some will guess right, some will guess wrong. Just let the guesses accumulate for a minute or two, without commenting.

"Ok, you've told me your guesses, and you've heard other people guessing. Is there anyone who wants to change the guess now? OK.

"Jim, what did I ask you to do? [Please keep the ball as exactly over the circle as you can.] Thank you. Some of the people out there think you're a liar, but I know you're not.

"I didn't tell Jim how to move his hand. I asked him to produce a certain effect on the ball, and he evidently agreed to try. And he evidently succeeded very well. But HOW did he succeed? What was he doing, inside, that created the result you saw? Now we're looking for something beside just a description of what we all could see happening. We're asking how Jim could be organized so he was able to do what you saw him doing. We're looking for an explanation of what we saw."

"You've all heard explanations of human behavior, according to one theory or another. You've probably found some explanations more convincing than others. I'd like to find out now what sort of explanation you think would apply to this little experiment. How do you think Jim works, which would explain what he was doing? For example, how may of you think that Jim could keep the ball over the circle with his eyes closed?" [Get a show of hands]. Nobody thinks you could do it, Jim. Let's get into position, and you close your eyes, and carefully follow this instruction; listen carefully: keep the ball exactly over the circle." [Jim closes his eyes, and you start moving your end of the rubber band around. This will provoke a bit of laughter.]

"Well, it's pretty obvious that Jim can't follow the instructions with his eyes closed. We have made a great discovery: when Jim closes his eyes, he becomes deaf."

"All right, if that's not it, what do we know now? Why did Jim have to see what was going on?"[More comments from audience].

"Let's try to get very specific. What exactly did Jim have to see in order to do what he did?" [Get more guesses — your hand, the ball, the rubber bands, whatever].

Well, let's test a couple of these ideas. If Jim had to see my hand, then it wouldn't make any difference if he couldn't see the ball, right? So we can just dispense with the rubber bands and the ball, and Jim can move his hand the way he thinks he needs to move it when I move my hand. When I say "freeze," Jim, just rest your hand on the paper and hold it there, and I'll do the same. Here we go."

[Perhaps it would be good for you both to have dry markers, to mark the position]

"Freeze. Now with my other hand I connect the rubber bands the way they were, and let's see where the ball is. [This is one reason for making sure that Jim can control very easily and accurately]. Well, not too bad. Are you satisfied with that, Jim? If not, go ahead and put your hand where you think it should be. [Jim corrects remaining error].

"Now, some other people said that Jim was looking at the ball. Suppose that's true: he can see the ball, but not my hand. I'll hold up this piece of cardboard with a notch in it, and Jim, you position yourself so you can see the ball but not my hand or arm. Ready? Here we go. [Experiment proceeds: use slow large disturbances. The piece of cardboard should be large enough to conceal entirely your half of the playing field]

"All right, we have the evidence now. What's your conclusion? [get some conclusions]. Of course we can use the last resort: Ask. Jim, while you're keeping the ball over the circle, are you looking at my hand or at the ball?" [The ball].

"Jim has served us well, but it's time to see if he's the only person in the world who can do this task. Let's thank Jim, and ask for another volunteer." [New volunteer].

OK, just a quick check: keep the ball exactly over the circle, Jane, while I hold up the cardboard — be sure you can't see my hand or arm." [30 seconds of demo]. Good, you work the same way Jim does. Would you like to try it with your eyes closed? No, I didn't think so.

"Can we agree now that watching the ball is sufficient? In other words, Jane doesn't HAVE to see my hand, and it probably wouldn't make much difference if she could because she could hardly keep the ball centered any better. Jane, why don't you sit down here for a little while, because I want to draw a diagram before we go on."

[Draw the rubber bands and ball with the target circle a little off from the ball]

“We’ve established that Jim and Jane look at the ball during this task. So they were looking at something in this region [draw a circle around target circle and ball]. Jane, did you also need to see where the target is?[Yes]. Jim, you too?[Yes]

“Now what does ‘seeing’ mean? We see with our eyes, of course, but what gets into our eyes has to get into the brain, too, before any perception happens. So let’s draw a box up here, with an arrow representing light rays coming into the box, and an arrow coming out that represents what the brain knows by way of these light-waves. Right at the end of the arrow coming out of the box, I’ll draw what the brain would be seeing right now, based on how the diagram looks. Here’s the ball, and here, away from it a bit, is the circle.”

“Jane or Jim, or both: if this is what you saw, what would you be trying to do? [Reply: Get the ball over the circle]. How would I draw a picture of that? [Reply: draw the ball inside the circle]. Like this? [Above and to the right of the picture of the perception, draw two concentric circles].

“So here we have a picture of how the ball and the circle actually look right now [indicate perception], and here we have a picture of — what, Jane or Jim, or anyone? [Wait for: How they are suppose to look, etc.].

“Would it be accurate to say that this [reference picture] is how you wanted them to look? [Yes] Is this how they always looked? [No]. Well then, how did you know how they were supposed to look? Before you answer, Jane, will you come up here again and do a short run with me?

[This time, move your end just rapidly enough so the ball wobbles all around the circle]. “Now, how did you want the ball and circle to look? [Jane tells you or points to picture]. Most of the time, how DID it look? [indicates perception somehow. If she doesn’t point to the pictures, you do it].

“OK, you knew it should look like this? [point to reference picture]. And most of the time it actually looked more like this? [point to perceptual picture]. Good. Well, if most of the time it looked like this [perception], how did you know about this? [point to reference picture].

“Let’s switch to another example for a moment. Most of you drive cars. When you going along a straight road, you steer the car to keep in its lane. What are you seeing out the windshield in front of you?” [Get descriptions]. Now consider: how do you know where it car is in its lane?” [More]. And finally, how do you know where it SHOULD BE in its lane? [etc.]

“All this is building up to a point that a lot of you may have seen by now. The remaining question is, WHERE is this knowledge of the way the car and road, or the ball and circle, should look? [In your head].

In your head. Can all of you imagine a ball centered in the circle, right now? Can all of you imagine the way the car and road look when you’re in the right position on the road? And where is that imaginary picture, right now? In your head — or at least, not anywhere in the room outside you. Even if you don’t actually see an imaginary image, there’s knowledge, somehow, of how the scene should look when it’s right. Right?

You're now ready to understand the theory of human behavior that's behind this presentation. Just a few more steps.

First, let's start using some consistent terminology. This arrow in the brain, up here, that shows how the ball and circle actually look right now, we'll call the perception. Notice that we don't call the actual ball and circle down here, the real ones, the perception. The perception is what the brain, up here, knows about the world, down here.

If the picture of the actual situation is the perception, then what can we call this other [reference] picture? It's not a perception of the actual ball and circle. It's an imagined perception. We judge the perception of the actual ball and circle with reference to this other picture, which just sits there unchanging, telling us how the actual perception should look, not now it does look. So let's call this other picture the "reference perception." Or we could say "the reference condition of the perception," or just "the reference condition." The key word is "reference," because it's with reference to this [reference picture] that we judge this [perception].

Now I ask you: is this [perception] the same as this? [reference]. How do you know that? What would you call the process you carry out in order to decide that they're not the same? [hope to get "comparison"].

We call it comparison, and when we draw models, we draw a box right here, which receives information from the perception and from the reference, and compares them. We call it a comparator. And what comes out of the comparator? [draw arrow]. Information about the difference between the perception and the reference. If there's no difference, no information comes out. If the perception is different, this arrow carries just the information about the difference. We can call this arrow a difference signal — in control theory it's called an error signal, and you can use that term too as long as you understand exactly what it means. It doesn't mean mistake or blunder, it just means that there's a difference. If there's any amount of error signal up here, we know that the real ball, down here, is not in the same position as the circle — or at least isn't perceived that way.

While we're at it, let's identify this other box down here. It's called an input function or a perceptual function. It receives light-rays or other physical information about the world, and converts it into some sort of representation in the brain. It creates a perception, or as we sometimes say a perceptual signal, that continuously indicates the state of the outside world. Right now, your brains contain some perceptual signals that indicate how my words are sounding and how I look as I stand up here. Obviously, everything in this region of the diagram is the brain [draw big circle] and the rest is outside the brain.

So way down here we have the actual circle and ball. Information comes from them into this perceptual function, creating this perceptual signal that always indicates the relationship of the circle and ball. Up here we have another signal, the reference perception or condition that's showing how the perception SHOULD be. And here is the comparator receiving both of those signals, comparing them, and spitting out a signal that represents how much difference there is — how far from the reference condition the perception is, and in what direction. These so-called signals are simply currents flowing through nerve fibers in the brain. But we don't have to worry about neurology here; this is about organization.

"Now if the perception looks like this, and the reference looks like this, what should Jim or Jane do? Obviously, move the arm so that the ball goes this way, toward the target. It would work equally well if the arm could make the target move the other way, toward the ball. And where is the information that tells which way to start moving? Right here, in the error signal coming out of the comparator.

"All we have to do is hook up this difference or error signal to Jane's arm muscles in the right way, and the arm will automatically move the ball, and keep moving it until there's no more difference signal to tell the arm to move some more. Let's watch it happen.

"Jane, if you'll assume the position —

"Center the ball. Thank you. Now we'll do this a little differently, in stop-motion. First, close your eyes. [move your end of the rubber bands to move the ball]. Now open your eyes and make what you see look right. Now close your eyes again [move in different direction]. Open again. Close again. Open again [etc.]. Thank you.

"By stopping the motion, we can see what's going on. Each time

Jane opens her eyes, she sees a different picture of the ball and circle. The reference condition is the same, so the comparator puts out a different error signal each time. This results in a different motion of the hand each time, and it's always in the right direction to make the perception move toward the reference condition." [Point to the right places on the diagram as you talk]

"When we stop the motion like that, we see what looks like a series of stimuli followed by responses. But when we do it in the natural way (Jane, one more time, please, with eyes open), you can see that there are no stimuli and responses. The difference or error is never allowed to get very big, unless I start moving this end of the rubber bands too fast. In fact, Jane is acting continuously to keep that error or difference signal from ever getting very large. By doing that, she is keeping the perception of the ball and circle very close to this reference picture. It takes only a very tiny error to make Jane's arm start moving to correct it; the effect of the movement is always just right to keep the error small.

"This is how you drive a car, isn't it? You don't wait for the wind or a tilt in the road to put you in the wrong lane, and then steer back. As soon as you can detect any difference between where you perceive the car to be and where you want it to be, you alter your steering efforts just enough to prevent that change from getting any bigger. So your car hardly wanders at all. At least that's how I hope you drive. These little corrections are quite automatic. You don't have to know about these signals in the brain or how they're hooked up. All you have to do is pick a reference condition. This little circuit here will then make sure that what you perceive matches what you intend to perceive. This little circuit is called a negative feedback control system. This reference signal is where you put your intention in.

"One last look. Jane, I'd like you to go into slow motion. Do everything just the same, but slow down your actions as if you have to push your arm through heavy syrup. Let's try it. I pull back on my end, and you slowly bring the ball back to the circle. You don't have to wait for my motion to finish; you can start acting right away, but make your action very slow.

[If this doesn't work you can change roles]

"Now you can see how disturbing the ball creates a little error, which starts the arm moving the right way. After a while the error is gone again. While my arm is moving, there's a continuous error, which is keeping her arm moving the other way; when my arm stops, she catches up and the error disappears. Thanks, Jane, it's been great.

"That was like seeing a slow-motion film of a control system in action. There's always a little error, a little lag, but not very much. The action is always pretty much equal and opposite to the disturbance, and the error is always pretty close to zero.

"Think back now to where we started, almost an hour ago. Jim got up here and moved his end of the rubber bands around, and you saw what he was doing, but did you understand what you were looking at? Now we have a model to explain what's happening. You can see why Jane or Jim's arm seemed to be mirroring my motions, as if imitating them. You can see why Jim acted to prevent me from having any influence on the position of the ball. You can see that what mattered was not how my arm moved, but how the ball moved. The actions of Jim and Jane were controlling the ball, not just reacting to my arm movements. They didn't even need to see my arm or what it was doing to the rubber bands. All they needed was to see where the ball was, and know where they wanted it to be. That explains everything you saw.

"When engineers work with system organized like the one in the diagram, they bring all sorts of complications into it. Things like differential equations, Laplace transforms and z transforms, Bode plots, sampling theory, and even information theory. But they're talking about the same system you see here, behaving just as you saw it behave, organized exactly as you see it organized in this diagram. A closed circle of cause and effect. Perception, comparison, and error driving an output — although of course they wouldn't talk about perceptions. You now understand the essence of this sort of system in just the way an engineer might understand it, and if you've followed the presentation, your understanding, you can be sure, is correct.

"The last thing we have to do is bring in a few more terms, and then we will be armed and ready to tackle the application of this concept to human behavior in the areas that interest you.

"At my end of the rubber bands we have something we will refer to as "the disturbance." We call the position of my end of the rubber bands the disturbance because it disturbs the ball, or would if there were no other influences acting on the ball.

"At the other end, we have the person's action. The term action means just what the person's muscles are directly causing to happen, positioning the hand. We can talk about the action without talking about any other effects it might have. The action is also an influence on the ball, but as you have seen, the behavior of the ball isn't the same as the action itself.

"And in the middle we have the controlled variable. In this case the controlled variable is the position of the ball relative to the circle. We call it a variable because it is capable of varying. We call it controlled because the actions of the person control it. The actions bring the controlled variable to a specific condition, and they vary in whatever way is needed to keep that variable in the same condition. That's what we mean by control.

"So in the environment of the person, we can see a disturbance, a controlled variable, and an action that is producing the control. In our model of what goes on inside the brain, we can see a perception that represents the controlled variable, a reference condition or signal that represents the intended state of this perception, and an error or difference signal that drives the action. Put all these elements together, and they add up to an explanation of the behavior you have been seeing. Put them all together, and you have a revolution in the behavioral sciences, which we're soon going to begin applying. Any comments or questions? We can take 10 or 15 minutes for them if you wish. I could go on with this presentation for about three days, so don't worry that we'll fail to meet a schedule. We'll just get as far as we can. The most important thing is that you understand, not that we finish an agenda.

____

After all the talk and milling around is done:

____

"Now let's talk about what behavior is. I need another volunteer just for a couple of minutes. You? Good, come on up. You will see that perceptual control theory, which is what we're talking about, gives a person a lot of confidence. It works with any randomly-selected person.

"Here's a dry marker. Hold it against the paper while you move your end of the rubber band, so it leaves a trace. Keep the ball exactly over the circle, right. Now just keep it there for a while. [put in a slow but broad pattern of disturbances].

"Thank you — that's all. Now suppose that someone had just come into this room, and heard me say "This trace was created by Pete's hand in the experiment you just saw." What might that person conclude about Pete's behavior?

"You can't say that Pete's behavior didn't produce this wavering and wandering trace. It did. But is that what Pete was doing? Was he really just making this squiggle on the paper? There's a saying among the adherents of PCT (which is what we call perceptual control theory) that goes "You can't tell what a person is doing just by looking at what the person is doing." Here's a beautiful example of that. What Pete did was to move the dry marker around and leave this trace. But what he was RE-

ALLY doing was keeping the ball over the circle. You, who know about the controlled variable that Pete was concerned with, understand that. But the person who came in late didn't see the controlled variable. The only evidence left is the record of Pete's actions, which tell us exactly nothing about what Pete was controlling by means of those actions.

"So you can't tell what a person is controlling just by looking at that person's actions. This is a profoundly revolutionary idea. In most ordinary aspects of life, we look at the people around us and we think we can see what they are doing. We look at their "behavior", in quotes. But what are we really seeing? We are seeing their actions. We are not seeing the variables that are being perceived by those people, and being controlled so that the perception is kept near some reference condition. Only the person we're looking at knows what perceptions exist, and what state of those perceptions that person would prefer to experience. Only that person can see the relevance of the action to maintaining control over a particular perception. We, observing from the outside, can't see the purpose of the actions.

"Imagine that we went through another session with this demonstration, but held a big piece of cardboard up so the audience couldn't see the ball and circle. You could see my hand on one side, and Pete's hand on the other side, and you could see them moving, but that's all. Wouldn't it seem that Pete's hand movements were being caused by mine? It would look as though Pete was watching my hand movements, and responding with symmetrical hand movements of his own. If you had to draw a diagram of what was going on, you'd draw it like this:

[Draw the rubber bands and ball. Draw a line from the disturbing end to a box and from the other side of the box to the action end].

The box is Pete. The movement of my end of the rubber band is sensed by Pete, and this stimulates him to move his end of the rubber bands. We have a nice simple cause-effect diagram, and Pete is just a link between the cause and the effect. If you grind that concept into your mind and really come to believe in it, what will happen when we take the piece of cardboard away? You'll see that the stimulus not only makes Pete's hand move, but tends to make the ball move because of the connecting rubber band. You'll see that Pete's hand movement also tends to make the ball move, but the other way. What an odd coincidence! The ball doesn't move at all, or hardly at all.

"Now if keeping the ball directly over the circle were vital to Pete's health and safety, you might begin to wonder how the stimulus knows that it should cause Pete to move his hand in just the way that's in his own best interests. You'd try to find an explanation that seemed less outlandish, one that didn't make it seem that Nature was being altruistic. So you might propose that keeping the ball over the mark was reinforcing to Pete. Whenever Pete didn't move the right way, the reinforcement wouldn't happen, so that wrong behavior would die out. Only the response to the stimulus that happened to keep the ball over the circle would be reinforcing, so that response would eventually be the only one left.

"You can see how it goes. Once you get a model firmly in mind and decide to believe it, all of your explanations from then on have to fit that model, even though they leave you with other mysteries. Just why should a ball being over a circle be reinforcing to Pete? You can't answer that question. All you know is that this explanation seems to work.

"We now have here a roomful of people who understand the control-theory explanation of what we've seen. You can compare the PCT explanation with the one we've just been through. While you're doing this comparison, consider this.

"The reinforcement explanation and the cause-effect model are the ones in which nearly every scientific psychologist has believed for most of this century. It's the one you learned in school. It's woven into our language and beliefs in ways that are so taken for granted that they're almost unconscious. Have you ever thought that by applying incentives to someone, you can get that person to behave differently? Have you ever explained your own behavior by pointing to something in your environment, and saying "that's why I did it"?

"Long ago, before anyone in this room was born, the great minds of psychology and biology help up a big piece of cardboard. They said, 'Never mind what's behind this piece of cardboard. Just look at this end of the rubber bands and that end of the rubber bands. Isn't it obvious that movements over here are causing Pete to move his hand over there? You don't need to talk about purposes and intentions and desires and wants and wishes. All you need to do is observe what causes what. And then you will be able to predict and control human behavior.'

"Everyone in this room who has studied the TQM moment knows what is wrong with that. People are not simply boxes with inputs and outputs, devices that can be made to act in certain ways by applying the appropriate stimuli. People have goals and desires and wishes and purposes and hopes and intentions. You ignore them only at great risk. The principles that Dr. Deming has given us are based on a deep awareness that people are not the kinds of devices that conventional science has told us they are.

"People are control systems. Deming realized this without having any formal understanding of why he knew they are as they are. He knew psychology was an important leg on which his approach stands — but he also knew that the psychology he needed was not the one that existed.

"PCT is the missing leg. It explains human behavior in a way that completely contradicts all conventional concepts, but which completely agrees with Deming's intuitive assessments. Perhaps even knowing only what you have learned in our simple little demonstrations, you can begin to get a feeling for how PCT is going to alter the psychological approach to management, and for that matter to getting along with people in general.

"Let's take a stretch and have some coffee for a while. When we come back I'll give you just a brief look at some of the ways PCT could be applied, and is being applied. Don't expect to become experts in the final half hour. All I hope for is to stimulate your imaginations, so you will begin to see what lies ahead. You can probably guess that learning how to turn this new understanding into practical action takes more than an introductory session. But I'm sure that by the time we finish, you'll be able to go home and work out a lot of the implications for yourself, and start putting PCT to work.

So.

That was more or less a role-play — what I'd say if I were doing the demo part of the presentation. Of course I'd speak differently from the way I write. The thing to pay attention to is the pace, and the plan. One thing at a time, always aimed at the next thing, and all working toward the final conclusions. A lot of patience and details, with demonstrations of everything. A lot of interaction with the audience. Always demonstrating exactly what you mean, never just generalizing. What you want is for the audience, at the end, to understand what they have seen in every detail, and to make the connections between the specific things they've seen and the parts of one elementary diagram. You want certain terms to be familiar — it doesn't matter if the terms are technical, there's no need to search for the magic word that will make it easy for them. You show them what each word means, and they'll understand.

I advise you to study this presentation, so you see how points to be made later are prepared early on, and how one idea leads to the next logical idea. Notice carefully that the only generalizations are at the very end, after all the specific hard-core ideas are laid in. And they are very sparing.

You're welcome to use any aspect of this material in any way that will help you. I hope you'll try it out, try to develop that sense of single-minded development toward one rather simple and specific goal: getting the audience to understand the organization of one simple control behavior. Once they understand that, they will grasp everything else you have to say very easily.

Best, Bill.

Rubber Band Demonstration

This booklet holds the script and original outline by Bill Powers for the video by the same name.

The Rubber Band Demonstration is described in several works introducing Perceptual Control Theory (PCT), starting with ***Behavior: The Control of Perception*** by Bill Powers. Bill Powers's outline in this booklet was an effort to improve on the presentation of the Rubber Band experiment performed before an audience of a Deming Users Group, called ***PCT supports TQM***, o few months earlier, a two hour recording available as a video. Bill's outline was embellished into the manuscript and presented with a group of friends in one take without rehearsal. I sincerely hope that the progression of illustrations shown and acted out here will facilitate the understanding of PCT by people who take the content seriously. ☺

Dag Forssell

Living Control Systems Publishing
2740 Gamble Court
Hayward, CA 94542–2402 USA
www.livingcontrolsystems.com

ISBN 0-9740155-2-0
9 780974 015521