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예측지원시스템에 의한 직관적 예측의 행태에 관한 연구

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Interactive Judgemental Adjustment of Initial Forecasts with Forecasting Support Systems

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■ Abstract ■

There have been a number of empirical studies on the effectiveness of judgmental adjustment to statistical forecasts. Generally the results have been mixed. This study examined the impact of the *reliability* and the *source* of the additionally presented reference forecast upon the revision process in a longitudinal time series forecasting task with forecast support systems. A 2-between(*reliability & source*), 2-within(*seasonality & block*) factorial experiment was conducted with post-graduate students using real time series. Judgmental adjustment was found to improve the accuracy of initial *eyeballing* irrespective of the reliability of an additionally presented forecast. But it did not outperform the *dampened* reference forecast. No effect was found of the way the source of the reference forecast was framed. Overall the subjects anchored heavily on their initial forecast and relied too little on the reference forecast irrespective of its reliability. Moreover they did not improve at the task over time, despite immediate outcome feedback.

1. Introduction

Despite sceptic views about the role of human judgement in decision making[49,18,32], most firms adopt judgemental approach as their primary method of forecasting[17]. A partial

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explanation for this is contained in Lawrence, Edmundson and O'Connor[19] who found that judgemental extrapolation was at least as accurate as statistical methods. It is also true that judgemental forecasters often possess extra model information lacked by the model[49,19] which would also encourage the use of judgemental forecasts.

A combination of statistical and judgmental forecasts has also been shown to improve accuracy significantly[36,10]. This combination mode can take the form of either simple averaging or an adjustment of statistical forecasts by people[44]. Recent developments in computer software(especially MRP II system) have increased the emphasis on judgemental adjustment of statistical forecasts. With these systems, sales forecasts are produced automatically. The task of marketing management for these systems is then to adjust these forecasts in the light of relevant marketing and other non-time series information. Thus many organizations are currently adopting the procedure of adjusting the statistical output forecasts of computer based statistical methods [37].

The important question is whether people are good at the task of adjusting the statistical forecasts that have been provided to them. Mahmoud[44] points out that "it is not clear exactly *how* managers combine their forecasts, *which* kinds of forecasts or techniques they combine and *when* managers obtain most benefit from combining(p. 599)." This study examined the way individuals adjusted their forecasts[1] in the light of a reference forecast and aimed to find out *the circumstances* in which judgemental adjustment would improve accuracy and *how* it was made. It was found that judgemental adjustment improved the accuracy of the initial judgemental forecasts regardless of the reliability of the reference forecasts. However the accuracy of the revised forecast did not exceed the high-reliable reference forecast itself due to their excessive discount of reliability and persistent reliance on their initial forecast. Moreover they did not learn reliability over time despite immediate outcome feedback.

There have been a number of empirical studies during the last decade on the effectiveness of judgmental adjustment to statistical forecasts and the results have been mixed. Some have cautioned against routine judgemental adjustment to objective forecasts[14,4]. On the other hand, intuitive adjustment has recently been reported as contributing to accuracy[45,46, 65].

Cross-sectional comparison across these studies is not a simple task due to their dissimilar research methods. McNees[42] comments that some of the vital factors influencing the effectiveness of adjustment include the forecaster's expertise, the importance of non-time series information and the model's reliability. A number of other task contingent factors [7] were also identified. This task reveals a number of missing links :

- Despite increasing use of graphical foreca-

1) The term *anchor*(Tversky & Kahneman, 1974) is avoided because there are two possible anchors in this study - a *base* or *initial forecast* and a *reference forecast*. In this study, the former refers to an eyeballed forecast based only on the graphical display of historical data and the latter, to the additionally presented model forecast.

sting packages, few *systematic* studies have been conducted on *interactive* graphical adjustment under varying conditions(cf. [64]).

- Even though the effectiveness of judgemental adjustment may depend upon the accuracy of the reference forecast, little research has systematically examined this issue[64].
- It is often the case in business that managers have their own *prior* forecast, expectation or goal[8]. Thus it is important to know whether the adjusted final forecast is more accurate than both the reference forecast and the initial forecast. Most studies have examined the former, not the latter.
- People may rely extensively on a provided reference forecast only to find that its alleged superior accuracy is questionable(witness the continued reliance on the Box-Jenkins method, despite empirical evidence that questions its general superiority - see[41]). The question, then, is whether people can learn to discern the *true* reliability of the forecast over time. No study has *systematically* investigated how a forecaster responds to the accuracy of the reference forecast with outcome feedback over the long run[cf. 46].
- An adjuster may have difficulty discriminating between *true* and *pseudo* reliability of the forecast. Little research has been conducted into the effect of the *source* of the forecast[26,16] on judgemental adjustment in a time series forecasting context.

This study was designed to explore these issues. The research questions are (1) does the reliability of the reference forecast provided affect the accuracy of any revised forecast? (2) does the impact of varying reliability of the reference forecast remain constant over time? (3) does the source of the reference forecast affect the revised forecast? (4) does the anchoring-adjustment heuristic[61] operate in revising their initial forecasts in the light of additional information? Relevant literature on these four issues is reviewed in the subsequent section.

2. Literature Review and Hypotheses

2.1 The Reliability of Statistical Reference Forecasts

The prevailing uncertainty as to the quality of judgemental adjustment may be partly due to an inadequate consideration about the reliability of a reference forecast. Discretion must be exercised over the reliability or predicability of the forecast before it is approved. Mistaken dependence on an unreliable forecast may lead to a deterioration in accuracy. Kahneman and Tversky[29] claimed that people ignore data reliability due to the operation of the *representativeness* heuristic. Anderson[2 : p.72] challenged that "the claim of the representativeness heuristic, that intuitive predictions are insensitive to information reliability[29 : p.273], has been found wrong." There have been a large number of empirical studies concerning *information reliability* in a variety of contexts - pedagogy[38], psychology [57,58,67,29], marketing[9], information purchasing[63], auditing[6], weather forecasting[40], medical diagnosis[33], velocity estimation[11], MCPL[66], communication[26] and memory recall [51]. An unequivocal conclusion is that people do consider information reliability in decision making. This notion has been generally supported in a time series judgemental adjustment task. Willemain[64] claimed that adjustment would improve accuracy when made from a reference forecast with a relatively large excess error whereas it would contribute little to the improvement of accuracy when made against a reference forecast with a low excess error. This conclusion was supported by Diamantopoulos and Mathews[46] and Wolfe and Flores[65]. Carbone et al.[14,15] also showed that judgemental adjustment was always beneficial when made from Box-Jenkins forecasts, which was the least accurate in their studies, despite their sceptical standpoint against routine judgemental adjustment. The first null hypothesis for this study is :

H_1 Adjustment improvement is not affected by the reliability of the reference forecast.

2.2 Reliability and Time

Despite abundant empirical studies with respect to reliability in a variety of task settings, surprisingly few studies examined the way people respond to variations of information reliability over time with outcome feedback. York et al.[67] examined the effect of reliability over time with outcome feedback. They found that reliability was found not to interact with time blocks (p>.9). On the other hand, Hogarth [25] argued that the effect of an anchoring-adjustment heuristic can be functional in a task with a *judgement-action-feedback* loop over time. A pertinent question, therefore, is whether the judgemental forecaster learns about the accuracy of the reference forecast and adjust his/her behaviour accordingly. The improvement would increase if they could learn about reliability over time in particular when the reference forecast is highly reliable. The second null hypothesis is :

H_2 Reliance on the reference forecast and adjustment improvement does not vary over time irrespective of its reliability.

2.3 Source

The reliance people place on the reference forecast may depend on their perception of the reliability of it. If they believe it comes from a reliable source, they would be more likely to use it in setting their own final forecast, than if the source is perceived as unreliable. It is possible that minor changes in the way an identical forecast is expressed[62] affects forecasters' perception of reliability about the source differently. Sternthal, Phillips and Dholakia[60 : p.285] stated that "communicator's character has a significant effect on the persuasiveness of their appeals." The relationship between source and reliability has received attention in feedback[54] and communication theory as well[26]. They defined the credibility of the source in terms of expertise and trustworthiness. There have been a number of studies([26,60] for a review) which examined the impact identical communication presented by different communicators had on opinion change. For example, Hovland et al.,[26] had two sources with different credibility present identical information to the subjects. They found that opinions were changed in the direction advocated by the high credible source greater than by the low reliable source. However it may not be the case in other settings. Connolly and

Thorn[16] questioned whether people would purchase differently between judgemental sourced and computer-generated sourced identical information in a management task. No significant variation in purchasing behaviour between these two sources was found. In a time series setting, the weight of academic opinion would seem to favour the proposition that the credibility of statistical forecasts was higher than judgmental forecasts[4]. Thus, it is possible that people would rely more on forecasts that were framed as *statistical* than on forecasts that were framed as *judgemental*. The third null hypothesis is formulated as :

H_3 Adjustment improvement is not affected by the *source* of the reference forecast.

2.4 Descriptive Adjustment Models

Although there are a number of *normative* models concerning judgemental revision(e.g., Bayesian, Shafer-Dempster Theory), they account inadequately for actual decision making [53,25]. A typical heuristic observed in revising initial opinion is *anchoring and adjustment*[61] due to cognitive limitations[25]. Wright and Anderson stated that "anchoring and adjustment is a two-stage mental heuristic... The first stage is recall of a previous judgement or generation of a preliminary judgement. The second stage is adjustment of the first-stage estimate, given the remaining information; typically the adjustment is in the expected direction but of insufficient magnitude." However, some researchers pointed out that "the theory of anchoring is incomplete: i.e., the hypothesised anchoring effect did not always occur and the magnitude of the effect was affected by other factors[30 : p.69]." A number of models have been proposed to capture the cognitive process of the heuristic. They include averaging[39] and the weight-additive model [2 : pp.78-79]. Their major concern centered around the way how the weights of information cues were attached. The weight-addictive model has a parallel with the exponential smoothing strategy, proposed as a descriptive model for anchoring-adjustment in a time series task[1,37]. Thus, the anchoring-adjustment heuristic can be modeled as :

$$\text{FINAL FORECAST} = \alpha \times \text{INITIAL FORECAST} + \beta \times \text{REFERENCE FORECAST} \quad (1)$$

One of the interests of this study is to understand the way α and β are intuitively weighted. An accurate forecast should be perceived as such[34,46] and relied upon more heavily than an inaccurate forecast. Concerning the extent of sensitivity to reliability(β in the above model(1)), early Bayesian researchers[53] found *conservatism*: that is, people glean less evidence from the data than warranted by the appropriate normative model. On the other hand, cascaded inference researchers[59] found the opposite, *excessiveness*, when people perform a *multi-stage reasoning task with unreliable data* [21]. That is, when asked to revise against questioned data reliability, people tend to make an insufficient discount of reliability(the *Best-Guess* strategy) and thus become excessive in estimation of posterior odds. With some exceptions[28,6], insufficient discount of unreliable information has also been manifest in numerous empirical anchoring-adjustment studies, which found that people tended to insufficiently adjust from an irrelevant external anchor. Thus the last null hypothesis is :

H_4 The anchoring-adjustment heuristic does not operate in a time series task irrespective of the reliability of the reference forecast.

In summary, the main objective of this study is what impact the *reliability* and the *source* of the reference forecast have upon the revision process and how the initial forecast is adjusted in a repetitive time series forecasting task.

3. Description of a Prototype Forecasting Support System

Most researchers of time series judgmental adjustment have concentrated on forecast accuracy and generally overlooked the complexities involved in its cognitive process. In addition, no empirical study has examined interactive judgmental adjustment of time series with forecasting support systems(FSS). This does not reflect the changes which computer information systems brought into business practice. We developed a forecasting support system, *Greviser* (Graphical Reviser), to be used in this study. *Greviser* is a decision support tool for forecasting. It provides four components typically featured in most DSS - data base, model base, user interface and feedback. Note that some of the following features are blocked from the subjects for the purpose of this study.

Data Base. FSS should allow forecasters to access information they want. *Greviser* provides past time series and(in some cases) causal information. The forecaster may need the time series sufficiently long enough to examine any pattern thought to exist in them[1]. Empirical forecasting research appeared to be inconsistent as to the number of time series points to display. Edmundson[19] presented 48-month series, with which people could examine meaningful seasonality patterns developed across four years. Angus-Leppan and Fatseas[3] also displayed 48-period monthly series. An interesting study which addressed this issue is Lawrence and O'Connor [37]. They found that those with the longer series(40 period) produced judgmental forecasts less accurately than those with the shorter series(20 period) ($p<.01$). The reason was attributed to that people may have believed "a change is overdue" (p.24) for the longer series. It is also quite possible that people did not utilise all the information contained in the longer series, ignoring some part of it. Following Lawrence and O'Connor[37], *Greviser* presents 24 points(2 years of monthly series) in line graph. In addition to the past time series presented, non-time series information can be also made available in some experiments. Icons can be displayed on the screen and people could interactively access any information they want.

Model Base. Greviser provides the statistical model to examine how it is combined with judgmental forecasts. In addition to the statistical model provided as part of judgmental adjustment, *Greviser* also allows a *what-if* capability. People simply indicate the weights for the information they want to use. Then, *Greviser* mechanically combines the information weighted by people. They may use this tool until they are satisfied with the weights they placed. Although some questioned the ability of people to indicate their subjective weights, *Greviser* takes away only the task of aggregation and leaves the role of judgment in specifying the weights. This would certainly reduce mental load(cf. [16]) and be less threatening to those who may feel afraid of being replaced by the model[18].

Graphical Interface. Recent developments in computer hardware and software have incorporated graphical presentation as an essential part of FSS. Often contrary to intuition, however, considerable amount of research showed that the graphical presentation of information is not necessarily decision effective, compared to the traditional tabular format. In 1984, DeSanctis (1984) reviewed prior literature which examined graphic *vs* tabular data presentation and concluded that the findings are equivocal. Since then, additional empirical studies have followed, only to add more conflicting results : Some found significant contribution of graphical format to decision performance, whereas others reported no difference between the two formats. To resolve these paradoxical findings, a contingent approach has been suggested by De Sanctis(1984) that "more researchers have not approached the graphics problem from the perspective of matching graph format with problem type"(p.470). In response to this, Vessey(1991) recently argued that graphic presentation could be most useful for spatial tasks whereas tabular, for symbolic problems . In the view of the fact that the nature of time series forecasting requires spatial comprehension of the time series, this task would be well catered by graphical presentation. To be consistent with this suggestion, most empirical studies of time series found that the graphical presentation of time series appeared to be a useful format in forecasting[36,3,64]. Following this guideline, *Greviser* adopts a graphical interface for judgmental adjustment.

Feedback. Most judgemental adjustment studies appeared to disregard the utility of feedback. This may be a reflection of the real world where feedback is often unavailable . This may also be due to the scepticism over the efficacy of outcome feedback raised in MCPL literature[22]. However, it appeared to be generally effective in forecasting contexts [56]. There are largely two components of feedback in time series judgmental adjustment tasks. People need to know their own performance. They also need to know the model's performance to determine whether or not to use it. *Greviser* provides bar-chart outcome feedback(percentage error) as to both forecasters and the statistical model. These two feedbacks are drawn in bar graphs at the lower part of the screen.

4. Research Methodology

4.1 Subjects

The subjects were 64 postgraduate students enrolled in an advanced post-graduate subject at the University of NSW, Australia. Most of them were part-time students with full-time employment in business. They were required to participate as part of the course as announced by the lecturer in charge. There were 'winner-takes-all' monetary incentives of A$50 for each experimental treatment[2].

4.2 Design and Time Series

This study was conducted as a 2-between, 2-within factorial design with repeated measures on the 2-within factors. The first between-subject factor, *the reliability of reference forecast*, consisted of two levels (1) high and (2) low reliability. The second between-subject variable was *source* - the way information on the source of the reference forecast was framed either as (1) a judgemental forecast or (2) a statistical forecast. The within-subject factors were two levels of *seasonality* and three levels of *blocks*. 10 monthly time series were chosen from the M-competition [41] with equal numbers of seasonal and non-seasonal time series. The task was expressed as sales forecasting and the nature of the series and the time period to which the series related were not provided [36].

4.3 Independent Variables Operationalization

The high-reliable forecast was the exponential *damped* smoothing forecast while the low-reliable forecast was the *naive* forecast. The reference forecasts were either expressed as coming from judgmental or statistical sources. Thus, for example, a *damped* exponential smoothing forecast could be expressed either as a statistical forecast or a judgmental forecast. Each subject forecasted one-period ahead for 30 iterations. To determine whether there was any change in improvement over time, these iterations were segmented into three time blocks due to parsimony[50].

4.4 Dependent Variables Measurement

Forecast accuracy was measured in terms of Mean Absolute Percentage Error(MAPE) because of its academic popularity[13] and robustness[5]. Since the effect of revision can best be understood by the degree of improvement over the criterion, *improvement* was measured in two ways as follows :

$$IMP_{base} = APE_{base} - APE_{revised}$$
$$IMP_{cue} = APE_{cue} - APE_{revised}$$

where $APE_{base}(APE_{revised})$ represents the Absolute Percentage Error of the initial(revised) judgemental forecast. Thus $IMP_{base}(IMP_{cue})$ represents the improvement in accuracy of the revised forecast over the initial forecast(the reference forecast provided). By having these two measures, a distinction could be made whether revision was beneficial over the initial forecast or the reference forecast.

4.5 Procedure

Subjects were randomly assigned to experimental conditions on entering the laboratory. They were briefed about the usage of the task instrument and how to win the prize money. Then they were asked to read a handout which contained *framing* information that identified the source of the additional reference forecasts. It was reinforced every trial through the *popup*

2) Some authors argue that the *winner-takes-all* incentive may increase pressure when the prize money is considerable and the chance is slim. However the subjects in this study had fairly high chance(10%) of winning it and this level of incentive seemed to motivate them considerably.

window on the screen. The subjects were asked to graphically extrapolate one-month ahead forecasts using a mouse. Then they were provided with the reference forecast to which they could, if thought necessary, revise their forecast made earlier. Subjects made 30 forecasts for two series - one seasonal and one non-seasonal time series.

5. Results

High intercorrelations and conceptual dependency among multiple dependent variables necessitated the employment of MANOVA[27]. Thus a 2-between, 2-within MANOVA was performed to test the major hypotheses of this study. When there was a significant multivariate effect, post-hoc univariate ANOVAs followed for each dependent variable to determine the nature of effect by manipulated factors. The Polynomial trend analysis was used for time blocks. An adjustment was made to control the inflation of α.

A 2 (*reliability*) × 2 (*source*) × 2 (*seasonality*) × 3 (*block*) MANOVA on IMP_{base} and IMP_{cue} revealed significant multivariate effects for *reliability*$(F(2,59)=23.60,\ p<.0005)$, *seasonality* $(F(2,59)=10.76,\ p<.0005)$, *block* $(F(4,238)=2.67,\ p<.05)$ and *seasonality* x *reliability* $(F(2,59)=9.00,\ p<.0005)$. No influence of *source* was observed[3] and thus hereafter *source* was disregarded $(F(2,59)=.62,\ p>.5)$. To investigate multivariate effects on individual dependent variables, post-hoc repeated measures ANOVAs were computed and reported subsequently.

5.1 Manipulation Checks

Reliability was successfully manipulated as intended across experimental conditions. The dampened exponential smoothed forecast ($MAPE_{dampen}$[4]=11.84) was significantly more accurate than the naive forecast ($MAPE_{naive}$=21.70), $F(1,60)=24.63,\ p<.0005$. The initial judgemental forecasts[5](MAPEbase=21.20) was not more ac curate than the naive forecast(p=.316). Whereas $MAPE_{base}$($MAPE_{base}$=22.04) was significantly less accurate than the dampened forecast($t(1919)=16.77,\ p<.0005$).

5.2 Improvement from Initial Judgemental Forecast : IMP_{base}

Reliability Effect. Overall the subjects benefited from their revision by 3.55%($MAPE_{base}$ 21.62)-$MAPE_{revised}$(18.07)). Table 1 reveals that IMP_{base} was significantly greater when $JUDGE_{base}$ was adjusted from the high reliable reference forecast(6.20) than from the low-reliable(0.89) $(F(1,60)=29.95,\ p<.0005)$. It is interesting to note that the beneficial effect of revision was also evident when a low-reliable

3) No *source* effect was found even for the first period(p=.8). The *Bootstrapping* models between the judgemental and the statistical source were also alike.

4) Hereafter $MAPE_{dampen}$ refers to the MAPE of the dampened statistical forecast, $MAPE_{naive}$, to the MAPE of the naive forecast, $MAPE_{revised}$, to the MAPE of the revised judgemental forecast and $MAPE_{base}$, to the MAPE of the initial judgemental forecast. Likewise, $JUDGE_{base}$ refers to the initial judgemental forecast, *$JUDGE_{revised}$ to the revised judgemental forecast*, CUE_{dampen} to the dampened forecast and CUE_{naive}, to the naive forecast.

5) To verify random assignment, a 2 × 2 ANOVA for $MAPE_{base}$ of the first period was computed and $MAPE_{base}$ did not differ in each experimental condition with respect to *reliability* and *source*(p>.9).

naive forecast was provided. Post-hoc paired t-tests showed that $\text{JUDGE}_{revised}$ was more accurate than JUDGE_{base} even when the naive forecast was provided($t(1919)=2.93$, $p=.003$). This suggests that some of the benefit from revision might have come from simple averaging and it will be discussed in detail later. Table 2 corroborates that adjustment from CUE_{dampen} led more frequently to positive IMP_{base}(20.1%) than did it from CUE_{naive}(8.2%). About 59% of all observations were not adjusted at all.

〈Table 1〉 Means of Adjustment Improvement in Reliability x Seasonality Experimental Conditions

	IMP_{base}		IMP_{cue}	
	Mean	SD	Mean	SD
When CUE_{naive} Given				
Seasonal Series	1.31	17.30	2.08	23.67
Non-seasonal	.47	7.46	.71	15.03
Average .89	13.32	1.39	19.83	
When CUE_{dampen} Given				
Seasonal Series	10.59	25.37	-6.07	17.52
Non-seasonal	1.81	7.70	-1.93	12.76
Average6.20	19.25	-4.00	15.46	

Seasonality Effect. There was a seasonality effect on IMP_{base}($F(1,60)=21.80$, $p<.0005$). IMP_{base} was greater for the seasonal series(5.95) than for the non-seasonal(1.14). People were initially inaccurate for the seasonal series but were able to improve by revision, more than did they for the non-seasonal series.

Reliability and Seasonality Effect. There was an interaction effect between *reliability* and *seasonality*($F(1,60)=14.83$, $p<.0005$). Table 1 shows that IMP_{base} was the highest (10.59) when the dampened forecast was provided for the seasonal series. Whereas IMP_{base} was the least with the naive forecast for the non-seasonal. Perhaps it suggests that for the seasonal series people were able to learn most from the provision of a reliable forecast that specifically dealt with seasonality.

Block Effect. Polynomial analyses were used to determine any change in improvement over three blocks. There was a significant decreasing linear trend of IMP_{base}($F(1,60)=7.57$, $p=.008$). It may be that over blocks MAPE_{base} became accurate linearly ($F(1,60)=10.42$, $p=.002$) whereas MAPE_{cue} did not ($F(1,60)$ $=40.46$, $p<.0005$). Thus these combined effects led to little benefit from the reference forecast and improvement over MAPE_{base} became harder. It was also expected that there may be a steady improvement in $\text{MAPE}_{revised}$ for the seasonal series as people learn the time series pattern over trials. A series of Polynomial analyses for $\text{MAPE}_{revised}$ indicated that there was a linear trend for the seasonal series($t(1123.4)=-3.62$, $p<.0005$) but there was a v-shaped quadratic trend($t(1623.8)=-4.03$, $p<.0005$) for the non-seasonal series. In other words, $\text{MAPE}_{revised}$ was less accurate for the seasonal series than the non-seasonal series in the first

〈Table 2〉 Frequency of IMP_{base} by Reliability

	When	CUE_{naive} Given	When	CUE_{dampen} Given	Total	
	n	%	n	%	n	%
Degraded	215	5.6%	264	6.9%	479	12.5%
Tie	1392	36.3%	885	23.0%	2277	59.3%
Improved	313	8.2%	771	20.1%	1084	28.2%
Total	1920	50.0%	1920	50.0%	3840	100.0%

$X^2=311.411$, df=2, $p<.0005$.

block whereas the reverse was true for the last block. Any learning effect for the seasonal series must be carefully understood in the light of the fact that $MAPE_{cue}$ showed a similar pattern. People could have performed better not because they were able to learn the characteristics of the seasonal pattern over time but simply because the reference forecast made available to them became more accurate over iterations. Nonetheless it can be concluded that there was no such confounding effect of the reference forecast because an analogous result was obtained for $MAPE_{base}$($F(2,120)=19.48$, $p<.0005$). Thus the learning effect for the seasonal series was due to their increased understanding of the seasonal pattern over time.

5.3 Improvement from Reference Forecast : IMP_{cue}

Reliability Effect. Judgemental revision was found to decrease the accuracy over the high-reliable forecast. Table 1 shows that there was negative IMP_{cue} for the dampened forecast while there was positive IMP_{cue} for the naive forecast. In other words, revision improved forecast accuracy over the low-reliable CUE_{naive} by 1.36% but deteriorated it over the high- reliable CUE_{dampen} by -4.0%($F(1,60)=31.77$, $p<.0005$). This suggests that there was not much excess error to improve when a reference forecast was highly reliable while the excess error would be substantial enough to improve on it when the reference cue was unreliable (Willemain, 1989, 1991). A positive correlation between IMP_{cue} and $MAPE_{cue}$($r = .31$[6], $p<.001$) corroborates that the more reliable the reference forecast was, the less the improvement. As a consequence, $MAPE_{revised}$ (15.84) adjusted from CUE_{dampen} was not as accurate as $MAPE_{dampen}$ (11.84) ($t(1919)=11.33$, $p<.0005$). On the other hand, the superiority of $MAPE_{revised}$(20.34) from CUE_{naive} was only marginally more accurate than CUE_{naive}(21.70) ($t(1919)=-3.08$, $p=.002$). The Chi-square analysis also showed Table 3 that $JUDGE_{revised}$ was less accurate in 60% of cases than the dampened forecast.

Reliability and Seasonality Effect. Reliability affected IMP_{cue} depending upon *seasonality*. Table 1 indicates that IMP_{cue} over the naive forecast was bigger for the seasonal series than for the non-seasonal series and the reverse was true for IMP_{cue} over the damped forecast. The reason may be two reference forecasts happened to be the most and least accurate in these situations. It accounts for why IMP_{base} was the most with the dampened forecast for the seasonal series as discussed earlier. It also cor-

〈Table 3〉 Frequency of IMP_{cue} by Reliability

	When n	CUE_{naive} Given %	When n	CUE_{dampen} Given %	Total n	%
Degraded	942	24.5%	1153	30.0%	2095	54.6%
Tie	7	.2%	6	.2%	13	.3%
Improved	971	25.3%	761	19.8%	1732	45.1%
Total	1920	50.0%	1920	50.0%	3840	100.0%

X^2 46.790, df=2, $p<.0005$.

6) In fact, it is a negative relationship by its nature.

roborates an earlier finding that the more reliable the reference forecast is, the greater the reduction in improvement from it.

5.4 Post-hoc Analysis : Adjustment Model

To understand the cognitive process of judgemental adjustment, the *model-of-a-man* [22] was constructed by regressing two cues - $JUDGE_{base}$ and the reference forecast - against $JUDGE_{revised}$ using step-wise regression. The main questions to be addressed in this section are (1) can adjustment process be modelled by an additive *bootstrapping* model? and (2) are they able to learn about the reliability of the provided forecast and change their adjustment mechanism accordingly?

Previous *bootstrapping* literature claimed that decision making could well be modelled by a linear regression model[32]. The regression model in this study was(see the model (1) in the literature review) :

$$JUDGE_{revised} = 0.654\ JUDGE_{base} + 0.346\ REFERENCE\ FORECAST\ (Adjusted\ R^2=0.993)$$

It shows that in general, the final forecast was approximately made by a $2/3_{\text{initial forecast}} + 1/3_{\text{reference forecast}}$ model : that is, a twice-greater weight for their $JUDGE_{base}$ than the reference forecast additionally presented. Table 4 indicates that people appeared to be sensitive, as expected, to the variations of cue reliability by allocating smaller weights to the low-reliable forecast(β =.26) and heavier to the high-reliable forecast(.44). However, comparison to the *normative* model[7] revealed as shown in Table 4 that overall they were conservative and insufficient irrespective of reliability. Moreover, there was no significant difference in accuracy between their *bootstrapping* model and simple averaging irrespective of the reliability of the reference forecast. It suggests that there would be no difference even though they are replaced by the simple averaging model. As seen in Table 4, the subjects' adjustment strategy was to anchor on their initial forecast with a weight of about 2/3 and then adjust according to their perception of reliability of the reference forecast provided : upward(2/3 plus about .08) for the high-reliable cue and downward(2/3 minus about .1) for the less reliable cue.

〈Table 4〉 Regression Weights Given to $JUDGE_{base}$ and the Reference Forecast[8]

	When CUE_{naive} Given		When CUE_{dampen} Given	
	subject	optimal	subject	optimal
$JUDGE_{base}$	0.743	0.554	0.565	0.139
CUE	0.257	0.428	0.436	0.852

A *reliability* x *time* interaction may be expected since over time dependence on the low-reliable cue should decrease and vice versa. The pattern of reliance placed on the reference forecast over time was investigated by looking at the coefficients attached to the reference forecast, varied over the number of periods

7) One of the difficulties for the research associated with a dynamic task[25] may include the development of a normative model[31]. In a time series task, however, it is reasonable to use the actual value as a criterion and the optimal model was derived by regressing $JUDGE_{base}$ and the reference forecast against the actual value.

8) Adjusted R^2>.98 for both the subjects' and the optimal weights.

elapsed(Table 5). For the first period, they have allocated higher weights to the reference forecast than the average irrespective of its reliability. However, overall reliance on both reference forecasts decreased over time. More surprisingly, dependence on the high-reliable cue decreased over time although they did not improve accuracy. On the other hand, it increased for the naive forecast in the second sector. This behaviour is detailed later in the discussion section.

<Table 5> β Coefficients on the Reference Forecast over Time[9)]

Periods	1	1-5	1-10	11-20	21-30	Average
When CUE_{dampen} Given	.612	.600	.608	.406	.344	.436
When CUE_{naive} Given	.372	.310	.273	.357	.181	.257
Average	.461	.448	.452	.370	.255	.346

5.5 Summary

- Eyeball initial judgemental forecasts were NOT more accurate than the random walk (*naive*) model.
- Judgemental adjustment from the high-reliable dampened forecast led to a reduction in accuracy of the reference cue itself. However it led to significant improvement over initial judgemental forecasts and even adjustment from the low-reliable *naive* forecast appeared to improve accuracy(H_1 rejected).
- There was a significant effect of *reliability* but no effect of *source* on *improvement* and *accuracy*(H_3 accepted).
- *Seasonality* affected accuracy and interacted with *block*. There was a learning effect only when the seasonal pattern existed, irrespective of the reliability of the reference forecast.
- Adjustment process could be modelled by a $2/3_{initial\ forecast} + 1/3_{reference\ forecast}$ model. They anchored on their internal forecast and adjusted upward for the high-reliable reference forecast and downward for the low-reliable forecast. Overall people tended to be conservative irrespective of the reliability of the reference forecast. The degree of conservatism was more severe for the high-reliable reference forecast(H_4 rejected).
- A moderate degree of dependence on the reference forecast was found for the first period but it decreased over time for the high-reliable reference forecast(H_2 rejected).

6. Discussion

Overall there was a significant effect of the *reliability* of the reference forecast on both *improvement* from the initial forecast and from the reference forecast. Firstly, adjustment led to significant improvement over the initial judgemental forecast regardless of the reliability of the provided reference forecast. There has been little research as to whether a revised judgemental forecast outperforms its earlier initial judgemental forecast. Carbone and Gorr[15] found that judgemental adjustment of an initial eyeball forecast improved accuracy. On the other hand, Angus-Leppan and Fatseas[3] reported that judgemental adjustment did not improve the initial eyeball forecast. Interestingly enough, we found that even adjustment from the low-reliable *naive* forecast appeared to improve the accuracy of initial eyeballing extrapolation. The revised

9) Adjusted R^2>.98 for all cases.

judgemental forecast always outperformed initial eyeballing for every time series irrespective of the seasonal pattern and the reliability of the reference forecast. This, however, may be due to mere averaging effect [36].

Secondly, an adjusted forecast from the dampened reference forecast was, however, always less accurate than the reference forecast itself. Thus judgementally adjusted forecasts were more accurate than the naive value yet still not more accurate than the dampened forecast. Conflicting results of empirical studies have been reported as to whether judgemental adjustment to statistical forecasts achieves higher accuracy. Mathews and Diamantopoulos[45,46] and Wolfe and Flores[65] present evidence of its improvement while Carbone, Anderson, Corriveau and Corson[14] and Armstrong[4] suggest it does not. One of the reasons why Mathews et al. [46,47,48] and Wolfe et al.[65] found that adjustment was beneficial could have been that for the real life forecasting situation, adjustments can be made for the important non-time series information. Willemain[64] claimed that adjustment would improve accuracy when made from a reference forecast with a relatively large excess error whereas it would contribute little to the improvement of accuracy when made against a reference forecast with a low excess error. This conclusion was supported by Wolfe and Flores [65]. The finding of this study supports the past literature that it would be hard to improve on the reference forecast when there is not much excess error left. This finding also corroborates that of Peterson and Pitz[52] who found that people's judgemental adjustment to their linear bootstrapping model did not outperform the model itself but their accuracy improved over that of their initial forecast.

Prospect theory[62] suggests that decision making is affected by the way the problem is framed. There was little effect of *source framing* on adjustment improvement and accuracy. This is consistent with Connolly et al. [16] which showed that source framing did not affect decision performance, but it conflicts with extensive literature on this issue[62]. This suggests that people were able to differentiate *true*-reliability and framed *pseudo*-reliability to an extent. Nonetheless we can not conclude that they were optimal in adjustment until comparison to the optimal model is made[e.g., *conservatism*, 53, *cascaded inference*, 59]. The *bootstrapping* model in this study confirmed that they were far from optimal and employed the anchoring-adjustment heuristic[61] in a time series task[10]. In other words, people anchored heavily on their initial forecast and any adjustment from it was insufficient, and only slightly affected by the reference forecast regardless of its reliability [61]. Given that the accuracy of the reference forecast was not perfect, this finding is in contrast to that of cascaded inference which claimed that *excessiveness* existed where there was insufficient discount of the questionable reliability of information. Conservatism was mainly due to anchoring[39] which was so persistent that the reliability of reference forecast was excessively discounted and taken little into account, contrary to cascaded inference. This behaviour has been observed in a number of anchoring-adjustment

10) It is true in that they anchored on the initial forecast. Some may argue that the anchoring-adjustment heuristic was not complied in that they did not anchor on the externally given reference forecast[28,6].

studies in an accounting task[28,6] which reported little anchoring on externally provided information in particular when the initial anchor was generated by the subjects themselves.

It should be however noted that, unlike earlier studies, this study was conducted in a repetitive task setting with immediate outcome feedback for 30 trials. Hogarth[25] argued that anchoring-adjustment may be functional with immediate and detailed outcome feedback provided on the error of both the reference and the subjects' forecast. This effect was not found in this study. Even though they were able to improve accuracy by learning the pattern of the seasonal series, their learning about the reliability was little or none. Rather the reliance they placed on the high-reliable reference forecast decreased over time despite feedback[11]. Two explanations can be offered for this behaviour. Firstly the reference forecast may not have been perceived as highly reliable. A post-experiment questionnaire indicated that their perception was high enough in this case. A second explanation is that they might have tried to beat the reference forecast rather than accept it[32]. Ashton(1990) argued that the provision of decision aid would change the nature of the task. If the model is highly accurate, it may put on pressure. Thus they may employ a trial and error strategy[52] using outcome feedback. Using this strategy, people may become inconsistent by trying to forecast random errors. This suggests that a decision aid should focus more on the initial forecast stage than the provision of more accurate forecasts.

Seasonality affected accuracy over time. There have been a few studies[14,64] which examined judgemental adjustment with respect to seasonality. Carbone et al.[14,15] showed some effect of seasonality whereas Willemain[64] did not. Cross comparison to these studies may not be plausible because they were not longitudinal studies. Mathews and Diamantopoulos[46] showed that accuracy improvement by adjustment varied over time. But they did not examine the *seasonality* effect. In our study, there was a learning effect only for the seasonal series, irrespective of the reliability of the reference forecast. In the light of the fact that an initial *eyeballing* forecast was produced without any aid or task relevant information and only historical time series data, it strongly suggests that the subject resorted to pattern-matching [23] to forecast and thus performance steadily improved for the seasonal series once they comprehended the characteristics of the seasonal pattern[55]. For anchoring-adjustment, on-line [24] pattern-matching might have worked better for the seasonal series.

Eyeball judgemental forecasts were found not more accurate than even the random walk model(naive). Carbone et al.[14,15] found that judgemental forecasts were less accurate than statistical forecasts. This conflicts with other research[3] which suggests that judgmental forecasts compare favourably with those of statistical methods. The reasons for inaccurate initial judgemental forecasts may be that the subjects may have paid less attention to their

11) It was questioned that little effect of feedback may be due to screen overload. Thus a separate follow-up experiment was conducted to further examine the effect of feedback. Three types of feedback was given with respect to their presentation format. A similar result was obtained apart from a finding that IMP_{cue} was greater for less overloaded feedback presentation.

initial forecasts because an opportunity was subsequently allowed for them to adjust in light of a new forecast provided.

In conclusion, this study showed that routine judgemental adjustment would not be recommended when the statistical model is quite accurate unless the forecasters have non-time series information for an abruptly changing situation to offset the model's assumption of constancy[41]. However when there is no model due to lack of historical data(e.g., new products), revision would be beneficial due to averaging effect provided that adjustment is made in a structured way[12] (e.g., asking an independent initial forecast). The result of this study may not be generalizable because this study was conducted with post-graduate students. However Remus[56] showed that MBA students could be used as surrogates of managers. More importantly, experts must possess contextual non-time series information. Thus it would be fruitful to replicate this study with experts in their context. In addition, learning without feedback may be further investigated to examine why outcome feedback was not helpful for decision performance(see [22]). Considering that judgmental adjustment is common practice in most companies, further research is needed to understand as to how a judgemental anchor is made and when decision aids can be most helpful for judgmental adjustment.

REFERENCES

[1] Andreassen, P. B. and Kraus, S. J., "Judgmental Extrapolation and True Salience of Change," *Journal of Forecasting*, 9(1990), pp.347-372.

[2] Anderson, N. H., "A Cognitive Theory of Judgment and Decision," in *New Directions in Research on Decision Making*, Brehmer, B., Jungermann, H., Lourens, P. and Seven, G.(eds.), Amsterdam : North-Holland(1986), pp.63-108.

[3] Angus-Leppan, P. and Fatseas, V., "The Forecasting Accuracy of Trainee Accountants Using Judgemental and Statistical Techniques," *Accounting and Business Research*, Summer(1986), pp.179-188.

[4] Armstrong, J. S., "The Ombudsman : Research on Forecasting : A Quarter- Century Review, 1960-1984," *Interfaces*, 16, 1 (1986), pp.89-109.

[5] Armstrong, J. S. and Collopy, F., "The Selection of Error Measures for Generalising about Forecasting Methods : Empirical Tests," Working Paper. 1992.

[6] Bamber, E. M., "Expert Judgment in the Audit Team : A Source Reliability Approach," *Journal of Accounting Research*, 21, 2 (1983), pp.396-412.

[7] Beach, L. R., and T. R. Mitchell, "A Contingency Model for the Selection of Decision Strategies," *Academy of Management Review*, 3(1978), pp.439-449.

[8] Beach, L. R., and T. R. Mitchell, "Image Theory : Principles, Goals, and Plans in Decision Making," *Acta Psycologica*, 66(1987), pp.201-220.

[9] Birnbaum, M. H., Wong, R. and Wong L. K., "Combining Information from Sources That Vary in Credibility," *Memory & Cognition*, 4, 3(1976), pp.330-336.

[10] Blattberg, R. C. and Hoch, S. J., "Database Models and Managerial Intuition - 50% Model + 50% Manager," *Management Sci-*

ence, 36, 8(1990), pp.887-899.

[11] Brehmer, B., "Inference Behavior in a Situation Where the Cues Are Not Reliably Perceived," *Organizational Behavior and Human Performance*, 5(1970), pp.330-347.

[12] Bunn, D and Wright, G, "Interaction of Judgemental and Statistical forecasting Methods : Issues and Analysis," *Mana gement Science*, 37, 5(1991), pp.501-518.

[13] Carbone, R. and Armstrong, J. S., "Evaluation of Extrapolative Forecasting Methods - Results of a Survey of Academicians and Practitioners," *Journal of Forecasting*, 1, 2 (1982), pp.215-217.

[14] Carbone, R., Anderson, A., Corriveau, Y. and Corson, P. P., "Comparing for Different Time Series Methods the Value of Technical Expertise, Individualised Analysis, and Judgemental Adjustment," *Management Science*, 5(1983), pp.559-566.

[15] Carbone, R. and Gorr, W. L., "Accuracy of Judgemental Forecasting of Time Series," *Decision Sciences*, 16(1985), pp.153-160.

[16] Connonlly, T. and Thorn, B. K., "Predecisional Information Acquisition : Effects of Task Variables on Suboptimal Search Strategies," *Origanizatianal Behavior and Human Performance*, 39(1987), pp.397-416.

[17] Dalrymple, D. J., "Sales Forecasting Prac tices : Results from a United States Survey," *International Journal of Forecasting*, 3 (1987), pp.379-391.

[18] Dawes, R. M. and Corrigan, B., "Linear Models in Decision Making," *Psychological Bulletin*, 81, 2(1974), pp.95-106.

[19] Edmundson, B., Lawrence, M. and O' Connor, M., "The Use of Non-time Series Information in Sales Forecasting : A Case Study," *Journal of Forecasting*, 7(1988), pp. 201-211.

[20] Flores, B. E., Olson, D. L. and Wolfe, C., "Judgemental Adjustment of Forecasts : A Comparison of Methods," *International Journal of Forecasting*, 7(1992), pp.421-433.

[21] Gettys, C. F. and Willke, T. A., "The Application of Bayes's Theorem When the True Data State is Uncertain," *Origanizatianal Behavior and Human Performance*, 4(1969), pp.125-141.

[22] Hammond, K. R., Summers, D. A. and Deane, D. H., "Negative Effects of Outcome-Feedback in Multiple-Cue Probability Learning," *Origanizatianal Behavior and Human Performance*, 9(1973), pp.30-34.

[23] Harvey, N., "Judgemental Forecasting in Univariate Time Series," *Journal of Behavioural Decision Making*, 1, 2(1988), pp.95-110.

[24] Hastie, R. and Park, B., "The Relationship Between Memory and Judgement Depends on Whether the Judgement Task is Memory -Based or On-Line," *Psychological Review*, 93, 3(1986), pp.258-268.

[25] Hogarth, R. M., "Beyond Discrete Biases : Functional and Dysfunctional Aspects of Judgmental Heuristics," *Psychological Bulletin*, 90, 2(1981), pp.197-217.

[26] Hovland, C. I. and Weiss, W., "The Influence of Source Credibility on Communication Effectiveness," *Public Opinion Quarterly*, 15 (1951), pp.635-650.

[27] Huberty, C. J. and Morris, J. D., "Multivariate Analysis Versus Multiple Univariate Analyses," *Psychological Bulletin*, 105, 2(1989), pp.302-308.

[28] Joyce, E. J. and Biddle, G. C., "Anchoring

and Adjustment in Probabilistic Inference in Auditing," *Journal of Accounting Research*, 19, 1(1981), pp.120-145.

[29] Kahneman, D. and Tversky, A., "On the Psychology of Prediction," *Psychological Review*, 80(1973), pp.237-251.

[30] Kinney, Jr., W. R. and Uecker, W. C., "Mitigating the Consequences of Anchoring in Auditor Judgments," *The Accounting Review*, LVII, 1(1982), pp.55-69.

[31] Kleinmuntz, D. N., "Human Decision Processes : Heuristics and Task Structure," In *Human Factors Psychology*, Hancock, P. A. (ed.), Elsevier Science Publishers B. V., North-Holland(1987), pp.123-157.

[32] Kleinmuntz, B., "Why We Still Use Our Heads Instead of Formulas: Toward an Integrative Approach," *Psychological Bulletin*, 107, 3(1990), pp.296-310.

[33] Knowles, B. A., Hammond, K. R. and Stewart, T. R., "Positive and Negative Redundancy in Multiple Cue Probability Tasks," *Journal of Experimental Psychology*, 90, 1 (1971), pp.158-159.

[34] Lawrence, M. J., "An Exploration of Some Practical Issues in the Use of Quantitative Forecasting Models," *Journal of Forecasting*, 2(1983), pp.169-179.

[35] Lawrence, M. J., Edmundson, R. H. and O'Connor, M. J., "An Examination of the Accuracy of Judgemental Extrapolation of Time Series," *International Journal of Forecasting*, 1(1985), pp.25-35.

[36] Lawrence, M. J., Edmundson, R. H. and O'Connor, M. J., "The Accuracy of Combining Judgemental and Statistical Forecasts," *Management Science*, 32, 12(1986), pp.1521-1532.

[37] Lawrence, M. J., Edmundson, R. H. and O'Connor, M. J., "Sales Forecasting Practices in Consumer Products Organisation," Working Paper, School of Information Systems, The University of NSW, Australia. 1993.

[38] Levin, I. P., Ims, J. R. and Vilmain, J. A., "Information Variability and Reliability Effects in Evaluating Student Performance," *Journal of Educational Psychology*, 72, 3 (1980), pp.355-361.

[39] Lopes, L. L., "Averaging Rules and Adjustment Processes in Bayesian Inference," *Bulletin of the Psychonomic Society*, 23, 6 (1985), pp.509-512.

[40] Lusk, C. M. and Hammond, K. R., "Judgment in a Dynamic Task : Microburst Forecasting," *Journal of Behavioral Decision Making*, 4(1991), pp.55-73.

[41] Makridakis, S., Anderson, A., Carbone, R., Fildes, R., Hibbon, M., Lewandowski, R., Newton, J., Parzen, E., and Winkler, R., "The Accuracy of Extrapolation(Time-series) Methods: Results of a Forecasting Competition," *Journal of Forecasting, 1* (1982), pp.111-153.

[42] McNees, S. K., "The Role of Judgement in Macroeconomic Forecasting Accuracy," *International Journal of Forecasting*, 6, 3 (1990), pp.287-299.

[43] Mahmoud, E., Rice, G. and Malhortra, N., "Emerging Issues in Sales Forecasting and Decision Support Systems," *Journal of the Academy of Marketing Science*, 16, 3 & 4 (1998), pp.47-61.

[44] Mahmoud, E., "Combining Forecasts : Some Managerial Issues," *International Journal of Forecasting*, 5(1989), pp.599-600.

[45] Mathews, B. P. and Diamantopoulos, A., "Managerial Intervention in Forecasting : An Empirical Investigation of Forecast Manipulation," *International Journal of Research in Marketing*, 3(1986), pp.3-10.

[46] Mathews, B. P. and Diamantopoulos, A., "Judgemental Revision of Sales Forecasts : a Longitudinal Extension," *Journal of Forecasting*, Vol.8(1989), pp.129-140.

[47] Mathews, B. P. and Diamantopoulos, A., "Judgemental Revision of Sales Forecasts : Effectiveness of Forecast Selection," *Journal of Forecasting*, 9(1990), pp.407-415.

[48] Mathews, B. P. and Diamantopoulos, A., "Judgemental Revision of Sales Forecasts : The Relative Performance of Judgementally Revised versus Non-revised Forecasts," *Journal of Forecasting*, 11(1992), pp.569-576.

[49] Meehl, P. E., *Clinical versus Statistical Prediction : A Theoretical Analysis and a Review of the Evidence*, Minneapolis : University of Minnesota Press. 1954.

[50] O'Brien, R. G., and Kaiser, M. K., "MANOVA Method for Analysing Repeated Measures Designs: An Extensive Primer," *Psychological Bulletin*, 97, 2(1985), pp.316-333.

[51] Olson, J. M. and Cal, A. V., "Source Credibility, Attitudes, and the Recall of Past Behaviours," *European Journal of Social Psychology*, 14(1984), pp.203-210.

[52] Peterson, D. K. and Pitz, G. F., "Effect of Input from a Mechanical Model on Clinical Judgment," *Journal of Applied Psychology*, 71, 1(1986), pp.163-167.

[53] Phillips L. D. and Edwards, W., "Conservatism in a Simple Probability Inference Task," *Journal of Experimental Psychology*, 72, 3(1966), pp.346-354.

[54] Podsakoff, P. M. and Farh, J., "Effects of Feedback Sign and Credibility on Goal Setting and Task Performance," *Origanizational Behavior and Human Performance*, 44 (1989), pp.45-67.

[55] Poulton, E. C., *Tracking Skill and Manual Control*, Academic Press, NY.1974.

[56] Remus, W., "Graduate Student as Surrogates for Managers in Experiments on Business Decision Making," *Journal of Business Research*, 14(1986), pp.19-25.

[57] Rosenbaum, M. E. and Levin, I. P., "Impression Formation as a Function of Source Credibility and Order of Presentation of Contradictory Information," *Journal of Personality and Social Psychology*, 10, 2(1968), pp.167-174.

[58] Rosenbaum, M. E. and Levin, I. P., "Impression Formation as a Function of Source Credibility and the Polarity of Information," *Journal of Personality and Social Psychology*, 12, 1(1969), pp.34-37.

[59] Schum, D., "Current Developments in Research on Cascaded Inference Processes," *In Cognitive Processes in Choice and Decision Behaviour*, Wallsten, T. (Ed.), Hillsdale, N.J. : Erlbaum. 1980.

[60] Sternthal, B., Phillips, L. W. and Dholakia, R., "The Persuasive Effect of Source Credibility : A Situational Analysis," *Public Opinion Quarterly*(1978), pp.285-314.

[61] Tversky, A. and Kahneman, D., "Judgment under Uncertainty : Heuristics and Biases," *Science*, 185(1974), pp.1124-1131.

[62] Tversky, A. and Kahneman, D., "The Framing of Decisions and the Psychology of

Choice," *Science*, 211(1981), pp.453-458.

[63] Wendt, D., "Value of Information for Decisions," *Journal of Mathematical Psychology*, 6(1969), pp.430-443.

[64] Willemain, T. R., "Graphical Adjustment of Statistical Forecasts", *International Journal of Forecasting*, 5(1989), pp.179-185.

[65] Wolfe, C.and Flores, B., "Judgemental Adjustment of Earnings Forecasts," *Journal of Forecasting*, 9(1990), pp.389-405.

[66] York, K. M., Doherty, M. E. and Kamouri, J., "The Influence of Cue Unreliability on Judgement in a Multiple Cue Probability Learning Task," *Origanizatianal Behavior and Human Performance*, 39(1987), pp.303-317.

[67] Youseff, Z. I. and Peterson, C. R., "Intuitive Cascaded Inferences," *Origanizatianal Behavior and Human Performance*, 10(1973), pp.349-358.