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Individual Zone of Optimal Functioning (IZOF): A Probabilistic Estimation

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The Individual Zone of Optimal Functioning (IZOF) model postulates the functional relationship between emotions and optimal performance, and aims to predict the quality of upcoming performance with respect to the pre-performance emotional state of the performer. Several limitations associated with the traditional method of determining the IZOF are outlined and a new probabilistic approach is introduced instead. To reliably determine the boundaries of the IZOF and their associated probabilistic curve thresholds, performance outcomes that vary in quality, as well as the emotional intensity associated with them, are taken into account. Several probabilistic models of varying complexity are presented, along with hypothetical and real data to illustrate the concept. The traditional and the new methods are contrasted in one actual set and two hypothetical sets of data. In all cases the proposed probabilistic method was found to show greater sensitivity and to more accurately represent the data than the traditional method. The development of the method is a first stage toward developing models that take into account the interactive nature and multidimensionality of the emotional construct, as well as the fluctuations in emotional intensity and performance throughout the competition phases (i.e., momentum).

Key Words: logistic model, emotions, performance

The Individual Zone of Optimal Functioning (IZOF) model is both a theoretical framework and a practical approach that enables qualitative and quantitative analysis of the functional relationship between emotions and performance (Hanin, 2000). The IZOF aims to predict the quality of upcoming performance with respect to the current or anticipated pre-performance emotional state of the performer. According to Hanin, the IZOF attempts to distinguish between poor

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and optimal performance based on documented emotional experiences associated with performance quality in a certain period of the performer's career. The IZOF model primarily emphasizes the within-individual dynamics of subjective emotional experiences associated with performance qualities (Hanin, 2000), so that emotional patterns of successful performances can be distinguished from the emotional patterns of less successful performances in each performer. "Methodologically, individually optimal (and dysfunctional) zones serve as empirically established criteria of an optimal performance state reflecting an individual's performance history. The zones are used to evaluate the degree of similarity (or discrepancy) between actually experienced... emotional state and this optimal state" (Hanin, 2000, p. 67). However, the traditional method of estimating IZOF contains several limitations. The purposes of this article are: (a) to elaborate on the methodological limitations of the traditional method of establishing the IZOF, and (b) to suggest a new method of estimation and conceptualization of the emotion/performance relationship.

Limitations in Determining the IZOF

Hanin (2000) defines optimal emotions in terms of the content and intensity of relevant subjective experiences under successful performance conditions. Optimal performance is associated with both pleasant and unpleasant emotions, feelings, and moods, which reflect idiosyncratic strategies and skills a performer might use in recruiting and using coping resources. The term *functioning* refers to the influence of specific optimal or nonoptimal (i.e., dysfunctional) emotions in the performance process (i.e., recruiting the resources needed for generating energy) and ultimately the performance quality. The IZOF model, according to Hanin, is a more efficient method of accounting for the dynamics of the emotion/performance relationship. Moreover, since the resources recruited and utilized by an athlete vary considerably across performers, one would expect a high degree of inter-individual variability in the content and intensity of emotions associated with successful and nonsuccessful performances.

Determination of the IZOF involves analysis of past performance history and emotional experience related to successful and unsuccessful performances, followed by multiple observations so as to refine the previously established zones. First occurs a series of observations of the performer for a given period of time, whether an athlete, musician, etc., in which emotional intensities and performance quality are observed simultaneously. This can also take the form of anticipation and/or introspection about emotion and performance. In this phase, optimal performances are selected as a criterion, and the mean and standard deviation of the corresponding emotional intensities are obtained. The IZOF is then determined by adding or subtracting 0.25 or 0.50 standard deviations, depending on the a priori decision and the scale in use, to or from the mean emotional intensity, which consists of many observations of optimal performances for a long period of time (Hanin, 1997).

To determine the "out of zone" region, one can consider "out" as the zones located above/below the upper/lower limits of the IZOF (Figure 1a). Also, an individual zone of dysfunction (IZDy) can be similarly determined. The poor (i.e., below expectation) performance related emotional intensities are averaged, and 0.25 or 0.50 of a standard deviation is added and subtracted accordingly. In this

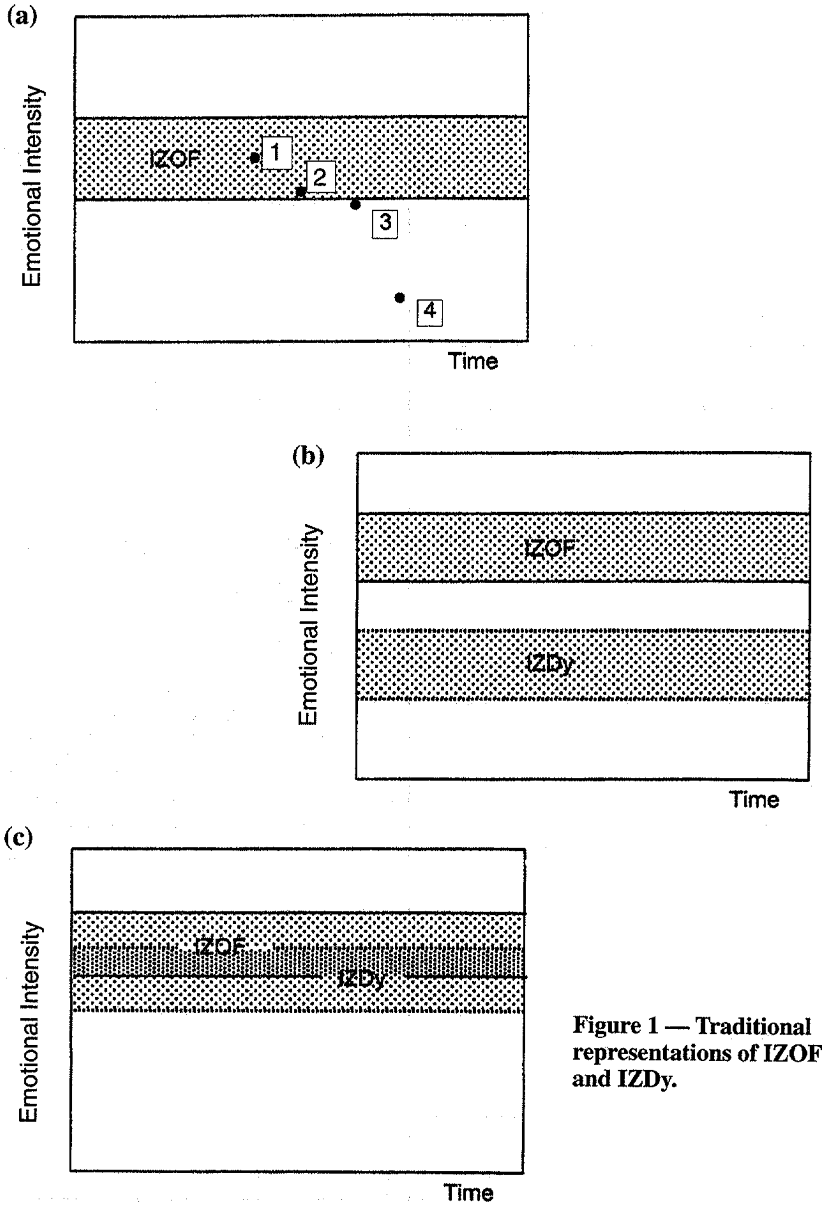


Figure 1 — Traditional representations of IZOF and IZDy.

way both optimal and dysfunctional intensity zones are determined, one designated as an IZOF and another as an IZDy (Figure 1b). In the second case, additional "emotion zones" exist in which the performer is neither in the optimal nor in the dysfunctional zone. Once a zone is determined, performance quality is predicted from the subsequent emotional intensities, based on the IZOF and the IZDy.

Traditionally, optimal and nonoptimal content emotions have been distinguished from each other (Hanin, 2000). The former are types of emotions associated with optimal performance while the latter emotions are associated with poor performance. Therefore the IZOF, as an optimal emotional intensity zone, has been associated with optimal content emotions while the IZDy, as a dysfunctional emotional intensity zone, has been associated with another set of emotions. This approach focuses mainly on selected intensity zones but not on the entire working intensity of each emotion. A more appropriate approach is to conceptualize IZOF and IZDy on the same continuum (Hanin, 1997, 2000). The reason is that optimal content emotions might not always be strongly associated with nonoptimal performance; the possibility exists that optimal content emotions may still be experienced in the presence of nonoptimal performance.

More important, the traditional estimation falls short because the IZOF is determined by measures of emotional intensity that fail to reflect the entire range of working intensity associated with all performance outcomes. This information is essentially conditional upon optimal performance, yet similar levels of emotional intensities are also experienced with performance that is less than optimal. Therefore it does not provide enough information to depict the relationship between optimal performance and emotional intensity.

If emotional intensities are similar between optimal and nonoptimal performances, typical emotional intensities for optimal performance are also typical for nonoptimal performance. In this case the association between optimal performance and emotional intensity is weak and cannot be predicted with certainty. On the other hand, if emotional intensities during optimal and nonoptimal performances are distinguished from each other, the association between performance outcomes and emotional intensity is strong and thus performance quality can be predicted with certainty. If all performance outcomes are not considered appropriately, there will likely be a large degree of inconsistency between observed and predicted performances.

The only case in which one can predict optimal performance based solely on the conditional information is when emotional intensities for optimal performance are *guaranteed not to overlap* with emotional intensities for nonoptimal performance. However, there has been some evidence that emotional intensities associated with optimal performance are also experienced when performance is less than optimal (Hanin, 2000). Therefore, information derived from *all* performance criteria is required for postulating a comprehensive estimate of the emotion/performance relationship, as it maximizes the overall correct classification rate of the data. In addition, as long as the IZOF and IZDy are determined independently, the relationship between the two zones remains unclear.

Hanin (1995, 1997, 2000) suggests evaluating the proximity of the athlete's current (or anticipated) emotional state and intensity to the previously established individually optimal and dysfunctional zones. A large discrepancy between the actual emotional state and the IZOF indicates a high probability of nonoptimal performance. Turner and Raglin (1996) likewise reported that performance quality decreased when the emotions experienced were further from the IZOF. This also supports the idea that the evaluation of emotional intensities should have a continuous as opposed to a categorical interpretation. For example, assume four states of emotional intensity—States 1, 2, 3, and 4 (see Figure 1a). States 1 and 2 are within the IZOF but they are relatively far apart from each other. On the other hand, State 3 is out of IZOF but very close to State 2, while State 4 is out of IZOF and far from State 3. A reasonable interpretation would be that State 3 "just missed" being located within the IZOF boundaries. It is still true, however, that State 3 is not associated with a high probability of optimal performance.

However, if we consider similarity of actual probability values of optimal performance for the four states of emotional intensity, it would be more reasonable to postulate that States 2 and 3 are more similar than States 3 and 4 or States 1 and 2. This interpretation is only possible when emotional intensity is conceptualized on a continuum. However, the traditional estimation of IZOF and IZDy provides sufficient information only for a categorical (i.e., in or out) interpretation, rather than a continuous interpretation (i.e., relative proximity of an emotional intensity to IZOF and IZDy). Since the traditional approach does not provide any information about the probability differences among various distances of emotional intensities from IZOF and IZDy boundaries, a relative interpretation of two different emotional intensities is difficult and in some cases impossible.

Another complication emerges when both zones, the IZOF and the IZDy, overlap. Common sense would dictate that the larger the overlap, the less chance of predicting the quality of performance from emotional states. As a matter of fact, empirical data from Hanin (2000) indicates a lack of overlap between the IZOF and IZDy with respect to four emotional categories: pleasant and functional (P+); pleasant and dysfunctional (P–); unpleasant and functional (N+); and unpleasant and dysfunctional (N–). However, there is still the possibility of overlap which cannot be ignored. This situation, if it indeed exists, indicates that the IZOF does not apply, as one has equal probability of performing optimally or poorly when experiencing similar emotional states (Figure 1c). This suggests a low discriminant validity of the emotional state/performance relationship. However, the current IZOF literature (e.g., Hanin, 2000) does not acknowledge how much overlap is indicative of a nonexistent IZOF, nor does it address how the width and distance between the IZOF and the IZDy might affect the certainty of the prediction of optimal or poor performance. Therefore, the IZOF estimation requires an extension from its present exclusive focus on successful performance to a wider concept that considers the entire range of individual performance.

Because of these contradictions and limitations, a more comprehensive estimation of the IZOF is required. Next, a probabilistic approach is presented that takes into account all possible performance criteria and emotional intensities. It is superior to the traditional approach because: (a) information from all performance criteria is used to determine IZOF and IZDy, and it always provides a better overall correct classification rate than the traditional method; (b) both IZOF and IZDy depend on continuous evaluation of the emotional intensities; and (c) the overlap of two different performance criteria are conceptualized as the overlap of the probability curves, thus avoiding any of the complications mentioned above.

Probability of Optimal Performance

The IZOF is defined as a zone of emotional intensity in which an individual has a higher probability of achieving an optimal performance than a nonoptimal performance. The procedure discussed in this section attempts to estimate probabilities of optimal performance and nonoptimal performance, given a specific emotional intensity. Several models which range in complexity levels represent this concept. In the models we present, the probability of any performance outcome criteria, including optimal performance, is assumed to be a function of emotional intensity in which the predictor variable is any measure of emotional intensity while the predicted measure is a performance outcome represented as ordered categories—poor, moderate, optimal, and the like, though other categories can be used such as below expectation, as expected, and above expectation.

In this paper, emotion is conceptualized as any variable that is measured on a scale and consists of items that represent it by using a response-format of intensity, for example a Likert scale. Though emotions are considered to be multidimensional (Hanin, 2000), the model refers to each dimension separately rather than as a matrix of variables. We later show how several related variables can be added in a similar method to create a profile of IZOF and IZDy.

The first model, Model 1, is the simplest way to determine IZOF by a probabilistic approach. It is assumed that the performance outcomes are represented by two categories, namely optimal or nonoptimal. Here, a nonoptimal performance is defined as any performance that is less than optimal, though not necessarily dysfunctional. Also, it is assumed that the probability of optimal performance monotonically increases as emotional intensity increases. Note that we could assume a monotonically decreasing function for optimal performance, depending on the type of emotional intensity measured. In order to determine an IZOF for this function, an application of a logistic regression model is a reasonable choice because the outcome variable is of a binary nature (i.e., either performing optimally or not).

In Figure 2, the predictor variable is any measure of emotional intensity, and performance outcome is binary. As depicted by the S-shaped curve in Figure 2, the probability of optimal performance increases with subsequent increases in emotional intensity. Under this model, IZOF is defined as the range that begins from the point at which emotional intensity provides a greater than 0.5 probability of optimal performance and beyond. This is the IZOF starting point, where the probability of optimal performance (solid line) exceeds the probability of nonoptimal

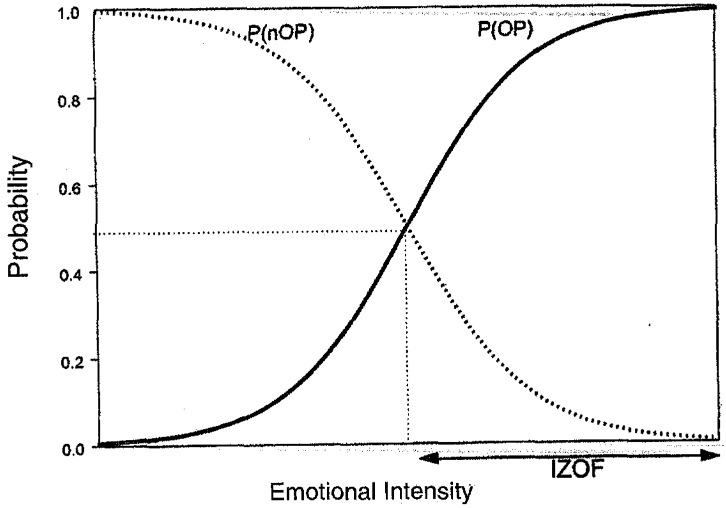


Figure 2 — Monotonically increasing probability model. Non-optimal performance (nOP); optimal performance (OP).

performance (dotted line). Accordingly, an IZOF has a lower boundary but no upper boundary. Similarly, an upper boundary, but not a lower boundary, can be determined for the zone of nonoptimal performance.

A monotonically increasing probability function for optimal performance may, in practice, be problematic because of the proximity of optimal performance. We can expect that the probability of optimal performance would be generally high if emotional intensity is high. However, the probability may decrease once emotional intensity continues to increase, as posited by the Inverted-U theory (Yerkes & Dodson, 1908). Instead of a monotonically increasing function, we can model the probability of optimal performance as a bell-shaped function, which increases along with emotional intensity and starts to decrease after its highest probability value associated with emotional intensity. A bell-shaped function would also coincide with Turner and Raglin's (1996) finding that performance quality decrements were largest when anxiety was within a one-standard-deviation range from IZOF, and smaller when the deviation from IZOF was larger. In this way an IZOF that has both upper and lower boundaries can be defined.

In order to model a bell-shaped function, two logistic regression models are used. The outcome variable in the first model is binary, where the value 0 is assigned for nonoptimal performance associated with low emotional intensity, and 1 otherwise. Two types of outcomes represent the value of 1. The first is optimal performance while the other is nonoptimal performance that is associated with high emotional intensity. As mentioned above, nonoptimal performance represents any less-than-optimal performance that is not necessarily an unsuccessful or poor performance. Here the probability of either optimal performance or nonoptimal performance with high emotional intensity is defined as P_1^+.

The second logistic regression model describes the probability of nonoptimal performance with high emotional intensity, and the probability is denoted P_2^+. In this second model the outcome variable has a value of 1 for nonoptimal performance with high emotional intensity, and 0 otherwise. Examples of the two logistic curves are shown in Figure 3a. The logistic curve for P_2^+ is always located on the right side of P_1^+, since the value of P_2^+ is always smaller than P_1^+, given the same emotional intensity, because P_2^+ is part of P_1^+. The probability of optimal performance is then expressed as $P_1^+ - P_2^+$. Also, the probability of nonoptimal performance with low emotional intensity is $1 - P_1^+$, and the probability of nonoptimal performance with high emotional intensity is P_2^+.

The relationships between these outcomes and probabilities are summarized in Figure 3c. Curves for $P_1^+ - P_2^+$, $1 - P_1^+$ and P_2^+, are provided in Figure 3b. As mentioned earlier, the IZOF is defined as the zone of emotional intensity within which the individual has a higher probability of optimal performance than nonoptimal performance. Figure 3b shows the IZOF as the interval between the two points where the curve for optimal performance intersects with the two curves for nonoptimal performance. This is identified as Model 2.

In practice, it is difficult if not impossible to distinguish nonoptimal performance with low emotional intensity from nonoptimal performance with high emotional intensity until an IZOF is determined. One possible solution is to code all nonoptimal performances simply as a nonoptimal performance while data are being collected. Once data collection is completed, the mean of emotional intensity for optimal performance ($\hat{\mu}_{OP}$) is computed. Then, nonoptimal performance associated with emotional intensity that is lower than $\hat{\mu}_{OP}$ is considered to be

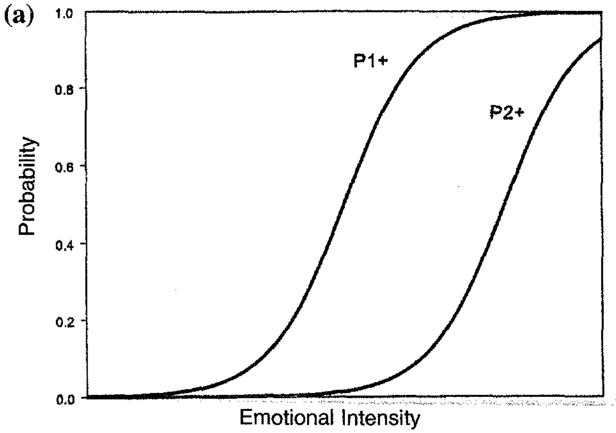
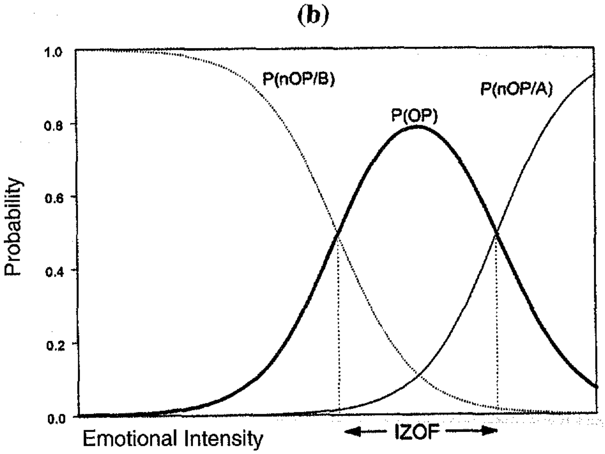
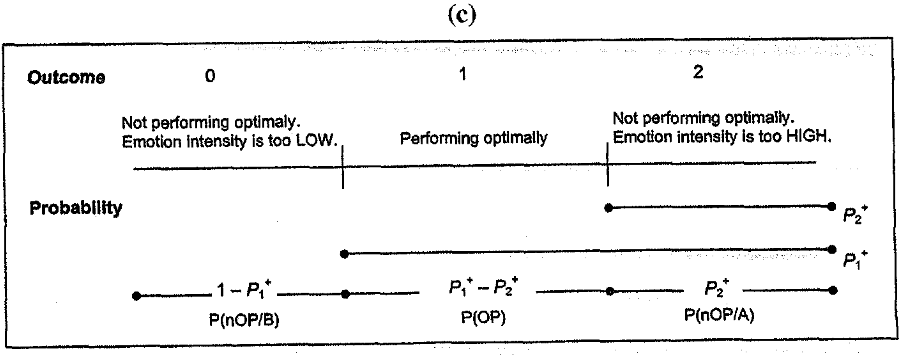


Figure 3 — Model 2: (a) Two logistic curves; (b) probability curves for 3 performance outcomes; (c) definition of the probability of optimal performance. Non-optimal performance with low emotional intensity (nOP/B); optimal performance (OP); non-optimal performance with high emotional intensity (nOP/A).





nonoptimal performance with low emotional intensity, while such performance associated with emotional intensity that is higher than $\hat{\mu}_{OP}$ is considered to be nonoptimal performance with high emotional intensity.

Model 3 extends Model 2 to predict both IZOF and IZDy. For this purpose, Model 3 distinguishes moderate performance from poor performance within the "nonoptimal" performance. Under the assumption that IZDy is observed when emotional intensity is below IZOF, we can now have four ordered performance outcome categories: 0 = poor performance; 1 = moderate performance associated with low emotional intensity; 2 = optimal performance; and 3 = moderate performance associated with high emotional intensity. Similar to Model 2, P_1^+, P_2^+, and P_3^+ are defined. P_1^+ is the probability of moderate performance with low emotional intensity (nOP/B), or optimal performance (OP), or moderate performance with high emotional intensity. P_2^+ is the probability of optimal performance or moderate performance with high emotional intensity. P_3^+ is the probability of moderate performance with high intensity (see Figure 4b). Therefore, the probabilities of the four performance outcomes are obtained by $1 - P_1^+$ for poor performance; $P_1^+ - P_2^+$ for moderate performance with low emotional intensity; $P_2^+ - P_3^+$ for optimal performance with high emotional intensity; and P_3^+ for moderate performance with high emotional intensity.

The relationships between these performance outcomes and probabilities are illustrated in Figure 4b. Exemplary probability curves for these four outcomes are shown in Figure 4a and identified as Model 3. Similar to Model 2, there are lower and upper boundaries for the IZOF. In addition to the bounded IZOF, we can also define the individual zone of dysfunctional performance (IZDy) with an upper bound. Similar to the distinction between nonoptimal performances with low emotional intensity and high emotional intensity in Model 2, moderate performance with low and with high emotional intensity in Model 3 can be distinguished based on the mean of emotional intensity for optimal performance.

In summary, IZOF and other zones are determined relative to each other based on the relationship between all the defined performance categories in the probabilistic approach. It is clearly a theoretical improvement from the traditional approach, because zones are determined by considering all performance outcomes. Also, the probability curve for each performance outcome overlaps the other curves and reflects the continuous evaluation of the zones. However, a zone does not overlap with the other zones. This is because the zones are determined as the interval of emotional intensity where the probability of the associated performance outcome is higher than for any other performance outcome. The choice of the model depends on the characteristics of a performer. For example, a performer might not show the inverted U-curve tendency for the relationship between emotion and optimal performance. In this case, one should not assume any higher performance outcome categories.

Examples of the Probability of Optimal Performance

Case 1. In this hypothetical case, it is assumed that the athlete's performance is evaluated 50 times and is placed into one of four ordered categories: poor performance = 0; moderate performance with low emotional intensity = 1; optimal performance = 2; and moderate performance with high emotional intensity = 3. Also, it is assumed that emotional intensity is measured by any state anxiety scale

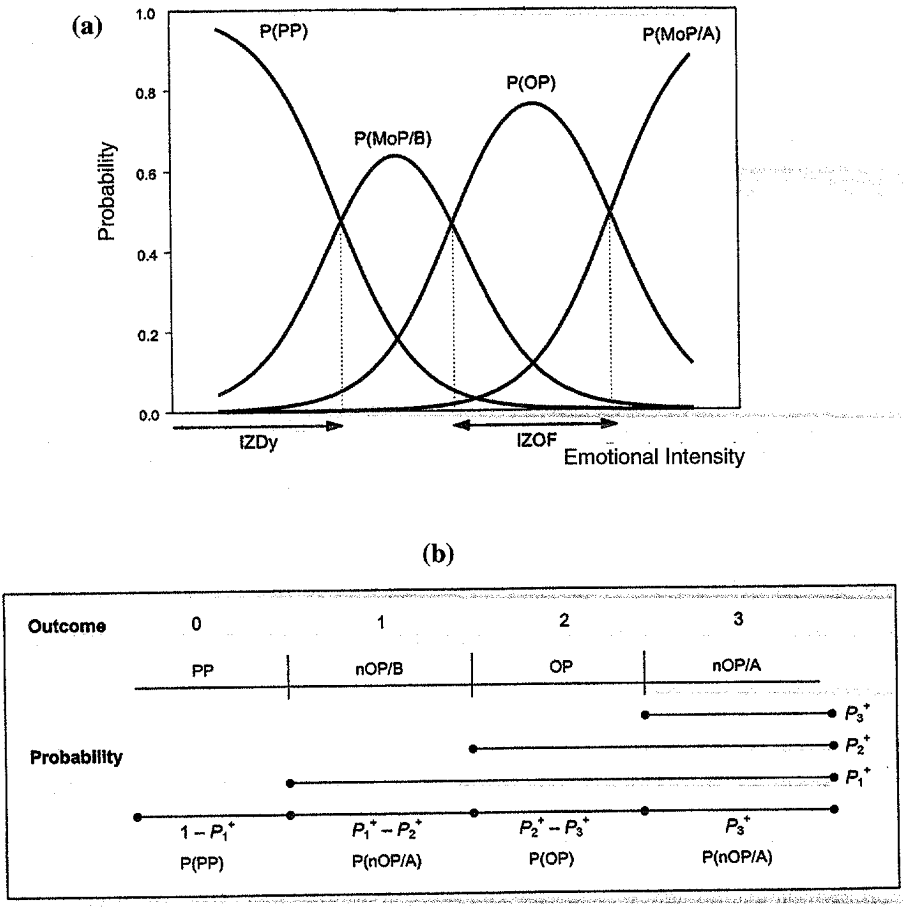


Figure 4 — Model 3: (a) Probability curves for 4 performance outcomes; (b) definition of the probability of optimal performance. Poor performance (PP); moderate performance with low emotional intensity (MoP/B); optimal performance (OP); moderate performance with high emotional intensity (MoP/A).

(SAS), together with the evaluation of each performance outcome. Higher scores on SAS indicate higher anxiety states. Summary statistics (frequencies for performance outcome categories, and means ± *SD*s of the SAS associated with them) of the data are presented in Table 1, and the scatter plot of the data is shown in Figure 5. Based on Hanin's empirical method, the IZOF for the individual is determined to be *mean* ± 0.25 *SD* = 57.90 ± 0.25(13.37) = (54.56, 61.24). Similarly, IZDy is determined to be 27.29 ± 0.25(6.70) = (25.62, 28.97).

In order to determine the IZOF and IZDy by a probabilistic approach, Model 3 is applied here, and the intercept (β_{0j}) and slope (β_1) for three logistic curves are estimated (see Table 2). It is assumed that the slope (β_1) is common to all logistic

Table 1 Summary Statistics for Simulated SAS Data, Case 1

	Outcome			
	PP = 0	MoP/B = 1	OP = 2	MoP/A = 3
Frequency	7	24	11	8
M	50.14	54.00	68.64	74.63
SD	3.53	4.77	4.50	2.33

Note: Poor performance (PP); Moderate performance with low emotional intensity (MoP/B); Optimal performance (OP); Moderate performance with high emotional intensity (MoP/A).

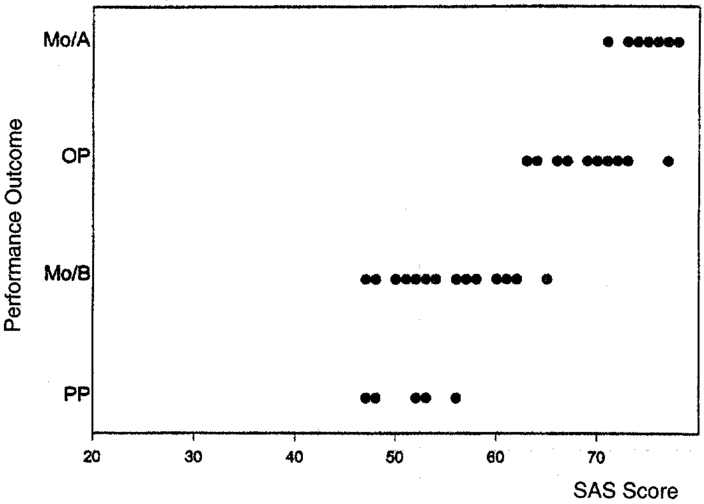


Figure 5 — Data plot, Case 1.

Table 2 Estimates of Intercepts and Slopes, Case 1

	P_1^+	P_2^+	P_3^+
β_{0j} (intercept)	22.262	28.969	33.500
β_1 (slope)	.460	.460	.460

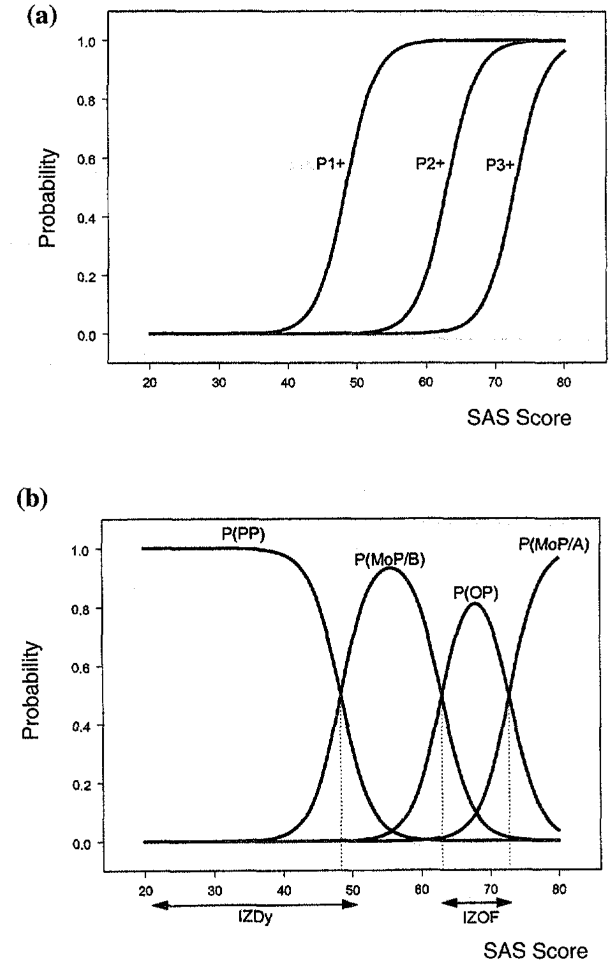


Figure 6 — Results, Case 1: (a) logistic curves; (b) probability curves for 4 outcomes: poor performance (PP); moderate performance with low emotional intensity (MoP/B); optimal performance (OP); moderate performance with high emotional intensity (MoP/A).

curves. If two logistic curves are allowed to have different slopes, the two curves could intersect and the probability of outcome performance categories would be less than 0. The constraint of the common slope prevents two logistic curves from intersecting and ensures that the probability of any outcome at any value of the predictor variable will be 0 or positive (see Appendix for more details of the model and the estimation of β_{0j} and β_1).

Based on the three sets of slope and intercept estimates, logistic curves for P_1^+, P_2^+, and P_3^+ are plotted and shown in Figure 6a. The probabilities of poor performance, moderate performance with low emotional intensity, optimal performance, and moderate performance with high emotional intensity are then obtained by $1 - P_1^+$, $P_1^+ - P_2^+$, $P_2^+ - P_3^+$, and P_3^+, respectively. These four probabilities are plotted in Figure 6b. Note that the limits of zones can be determined algebraically by β_{0j}/β_{1j}, and they are 48.40, 62.98, and 72.83. Therefore, based on the probabilistic approach, the IZOF is determined to be (62.98, 72.83). According to the

Table 3 Estimated Zones and Correct Classification Rate, Case 1

Estimation method	IZOF	IZDy	Correct classification: Within zones	Correct classification: Outside of zones	False classification: Within zones	False classification: Outside of zones
Traditional						
0.25 *SD*	(67.52, 69.77)	(49.26, 51.02)	1	29	3	17
0.50 *SD*	(66.39, 70.90)	(48.38, 51.90)	3	29	3	15
Probabilistic	(62.98, 72.83)	(20.00, 48.40)	13	26	6	5

theory, this is the range in which the individual has a higher probability of optimal performance than any other performance outcome, and this is consistent with Figure 6b. Also, it is indicated that the IZDy for this individual is (20, 48.40).

Table 3 provides a summary of estimated zones (IZOF and IZDy) and correct and incorrect classifications from both traditional and probabilistic methods. For the traditional method, both ± 0.25 and ± 0.50 *SD* criteria were used. The two traditional methods classified only 1 and 3 within-zone observations for ± 0.25 and ± 0.50 *SD* criteria, respectively. These narrow zones resulted in more false classifications that fell outside the zones (i.e., 17 for the ± 0.25 *SD* criterion and 15 for the ± 0.50 *SD* criterion). This indicates that the determinations of the zones were far too conservative. The probabilistic method, on the other hand, had much wider zones than the two traditional methods and obtained more correct classifications within the zones ($n = 13$). Also, the incorrect classification outside the zones decreased dramatically ($n = 5$). The ratios of correct-to-false counts within the zones were 1:3, 1:1, and 1:0.46 for the ± 0.25 *SD*, ± 0.50 *SD*, and the probabilistic method, respectively. Similar ratios for the outside of the zones were 1:0.59, 1:0.52, and 1:0.19, respectively. This indicates a clear advantage of correct-to-false classification ratio for the probabilistic method. Overall, the probabilistic method had the highest correct classification rate, 78% vs. 60% and 64% for the two traditional methods.

Case 2. Another hypothetical example is presented in which an IZOF should not be determined. Similar to the first case, Model 3 is assumed—four outcome categories and three logistic regressions—and the emotional intensity is measured by SAS. The descriptive statistics are summarized in Table 4 and the scatter plot for the data is presented in Figure 7. Based on the descriptive statistics, the IZOF by the traditional approach is obtained as 63.33 ± 0.25(6.03) = (61.82, 64.84). Similarly, the IZDy is determined as 43.75 ± 0.25(6.18) = (42.20, 45.30). Thus, according to the traditional approach, the two zones are distinguished from each other and the IZOF can be clearly determined.

On the other hand, based on the probabilistic approach, slopes and intercepts for the three logistic curves are estimated as indicated in Table 5, and probability functions are obtained and plotted in Figure 8a and 8b. The plot indicates that the probability of optimal performance never becomes the highest among the four

Table 4 Summary Statistics for Simulated SAS Data, Case 2

	Outcome			
	PP = 0	MoP/B = 1	OP = 2	MoP/A = 3
Frequency	4	24	3	19
M	43.75	54.71	63.33	69.63
SD	6.18	6.48	6.03	3.62

Note: Poor performance (PP); Moderate performance with low emotional intensity (MoP/B); Optimal performance (OP); Moderate performance with high emotional intensity (MoP/A).

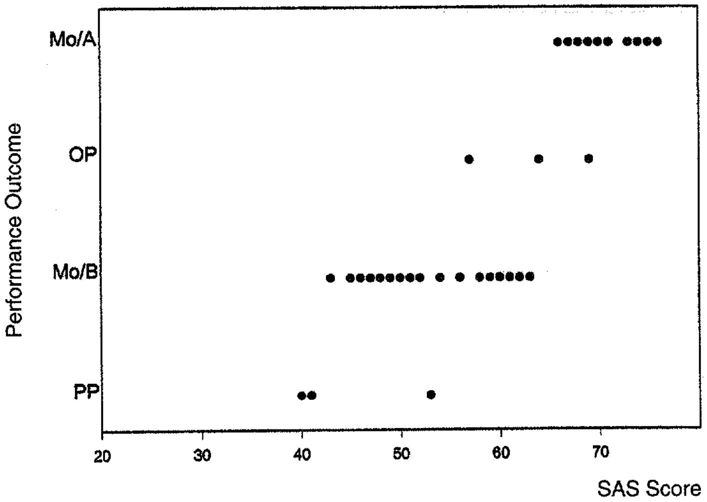


Figure 7 — Data plot, Case 2.

Table 5 Estimates of Intercepts and Slopes, Case 2

	P_1^+	P_2^+	P_3^+
β_{0j} (intercept)	23.623	34.108	35.161
β_1 (slope)	.543	.543	.543

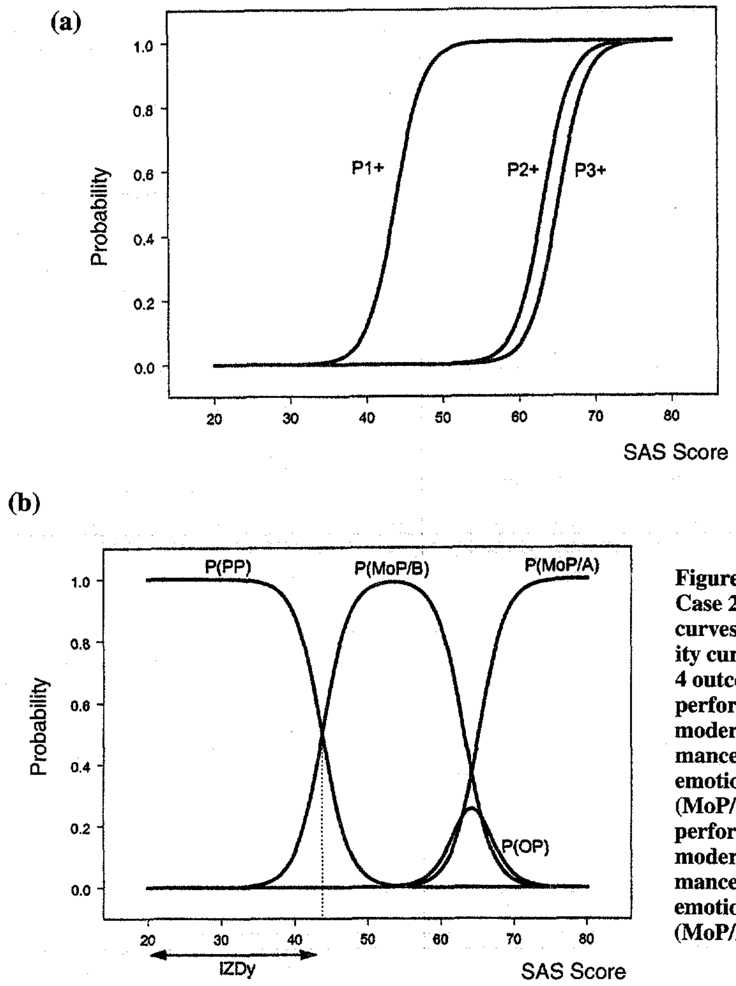


Figure 8 — Results, Case 2: (a) logistic curves; (b) probability curves for 4 outcomes: poor performance (PP); moderate performance with low emotional intensity (MoP/B); optimal performance (OP); moderate performance with high emotional intensity (MoP/A).

Table 6 Estimated Zones and Correct Classification Rate, Case 2

Estimation method	IZOF	IZDy	Correct classification		False classification	
			Within zones	Outside of zones	Within zones	Outside of zones
Traditional						
0.25 *SD*	(61.82, 64.84)	(42.20, 45.30)	1	38	5	6
0.50 *SD*	(60.31, 66.35)	(40.65, 46.85)	3	28	15	4
Probabilistic	n/a	(20.00, 43.50)	3	42	1	4

possible outcomes at any SAS score. Therefore an IZOF should not be determined for this data. On the other hand, the probability of poor performance becomes larger than the other performance criteria when the SAS score is lower than $\beta_{01}/\beta_1 = 43.50$. Therefore IZDy is defined as (20.00, 43.50). Table 6 summarizes the estimated zones (IZOF and IZDy) and correct and incorrect classifications from both traditional and probabilistic methods.

The two traditional methods had low correct classification rates and high incorrect classification rates within the zones. The ratios of correct-to-false counts within the zones were 1:5, 1:5, and 1:0.33 for the ± 0.25 *SD*, ± .50 *SD*, and the probabilistic method, respectively. Similar ratios for the outside of the zones were 1:0.16, 1:0.14, and 1:0.009, respectively; again, a clear advantage of correct-to-false classification ratio for the probabilistic method. Overall, the probabilistic method had the highest correct classification rate, 90% vs. 78% and 62% for the two traditional methods.

The differences between the traditional and probabilistic estimations are observed in both cases. These differences are attributed to the advantage of the probabilistic approach in taking into account the frequencies associated with all types of performance outcomes simultaneously and integratively. It considers the dispersion of the emotional intensity measures for all performance outcomes and determines the zone for each one. In other words, the probability function of a particular performance outcome is determined in relation to other performance outcomes. For example, the probability of optimal performance will be relatively high if many optimal performances are observed relative to other performance outcomes. Case 1 exemplifies this. On the other hand, if optimal performances are rare, relative to other performance outcomes, the probability of optimal performance will decrease sharply, as exemplified in Case 2. Both cases demonstrate that the probabilistic method provided the highest correct classification rate among the three methods.

Real Data Analysis

Data that depict the relationship between reaction time (RT; performance) and palmar skin resistance (PSR; anxiety) in Freeman (1940) are analyzed to estimate the IZOF and the IZDy with the probabilistic approach. In the original data, the RT and PSR were recorded in a series of 105 trial observations from a single individual. For this analysis, reaction time was coded into one of three performance outcomes: optimal = 110 milliseconds (ms) or faster, moderate = 110 to 150 ms, and poor = 150 ms or slower. In order to distinguish between moderate performances with low and high anxiety states, the average PSR (in ohms) for optimal performance was obtained ($M = 24{,}000$, $SD = 10{,}320$, $n = 24$). Then, a performance with PSR <24,000 was coded as moderate performance with low anxiety, and a performance with PSR $\geqslant$ 24,000 was coded as moderate performance with high anxiety. As a result, moderate performance with low anxiety had PSR of $M = 16{,}157$ and $SD = 4{,}233$ with $n = 21$, and moderate performance with high anxiety had PSR of $M = 41{,}694$ and $SD = 9{,}145$ with $n = 38$. Poor performance had PSR of $M = 45{,}363$ and $SD = 21{,}929$ with $n = 22$.

With four ordered category outcomes, Model 3 was applied for this case. The estimate of the slope was $\beta_0 = -0.11$ and the estimates of intercepts were $\beta_{11} = -6.21$, $\beta_{12} = -3.47$, and $\beta_{13} = -1.52$. Note that the unit of intercepts is in 1,000

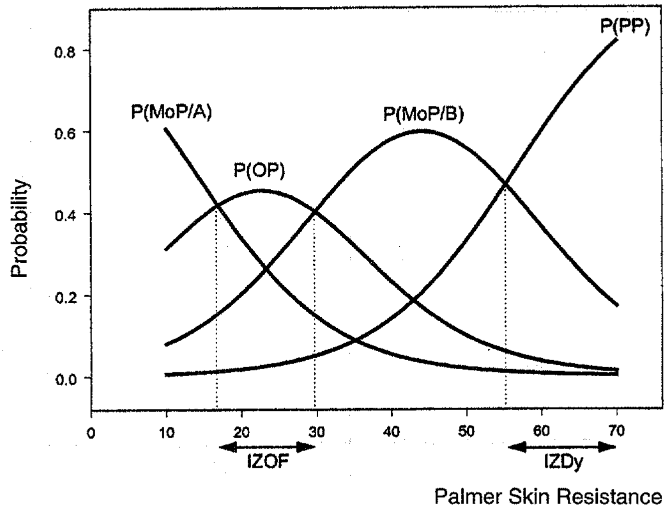


Figure 9 — Probability curves for data from Freeman (1940).

ohms. These estimates obtain the boundaries $\beta_{11}/\beta_0 = 56.45$, $\beta_{12}/\beta_0 = 31.55$, and $\beta_{13}/\beta_0 = 13.82$. Therefore, IZOF is (13.82, 31.55) and IZDy is 56.45 or greater. With these zones, correct classification rate was 54%. With the two traditional methods, correct classification rates were 39% and 33%, for ± 0.25 and ± 0.50 *SD* criterion, respectively. Again, the probability method demonstrated the highest correct classification rate. The probability curves are presented in Figure 9.

A Multivariate Conceptualization of the IZOF

The above procedure can be directly applied to the determination of IZOF and IZDy for multidimensional measures of emotional intensities. For example, the four dimensions of pleasant/unpleasant emotions (positive-negative affect; PNA; Hanin, 2000) are considered here. P+ and N+ are pleasant and unpleasant emotions that affect performance in a positive way. This implies that the higher the P+ and N+ emotions, the higher the probability of performing optimally. Therefore, it is expected that IZOF is located in the upper pole of the emotional intensity scale while IZDy is located in the lower pole of the emotional intensity scale. This is the type of emotional intensity that was modeled in the previous two sections. On the other hand, P– and N– are pleasant and unpleasant emotions that increase the probability of nonoptimal performance. Therefore, it is expected that the IZOF is located in the lower pole of the emotional intensity scale while IZDy is located in the upper pole of the emotional intensity scale.

The probabilistic approach is applied to each of the four measures of emotional intensity separately to determine IZOF and IZDy. Once they are determined, they can be used to predict the probability of optimal or poor performance for each of the four dimensions. Examples of probability curves for the four dimensions are illustrated using Model 3 in Figure 10. As mentioned above, the curves in Figure

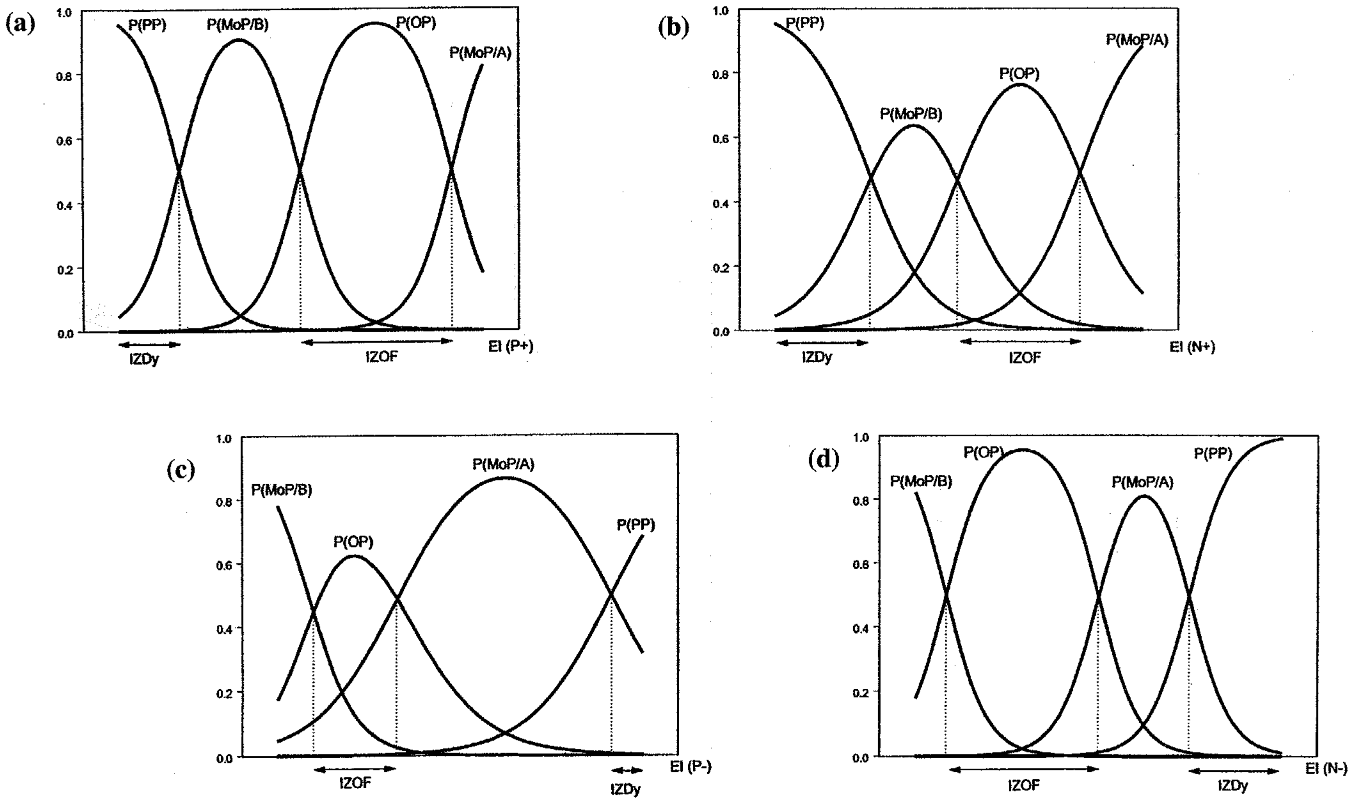


Figure 10 — Exemplary multidimensional representation of IZOF and IZDy: (a) P+, (b) N+, (c) P–, (d) N–. Poor performance (PP); moderate performance with low emotional intensity (MoP/B); optimal performance (OP); moderate performance with high emotional intensity (MoP/A).

10 describe or predict four sets of probabilities for each type of emotional intensity separately. It makes sense to compare the zones from four types of emotional intensities in an attempt to identify similarities and differences across all four. In Figure 10, for example, the individual has a wider IZOF for P+ than for N+, and a narrower IZDy for P– than N–. This kind of profiling for multiple emotional intensities may help us understand the emotional characteristic of each athlete with respect to each emotional dimension. Such a procedure can be applied using any scale that measures emotions and is multidimensional in nature.

Summary

The theory of IZOF has been aimed at predicting performance outcomes based on comparisons of the current state (emotion) with a previously established emotional intensity. Therefore the IZOF theory has been conceptually probabilistic. However, we have pointed out that using the traditional approach to determine the IZOF does not provide a comprehensive estimation of the zone, because it relies on conditional information of emotional intensity on a particular performance outcome. Also, it was pointed out that separately determining IZOF and IZDy would result in some difficulties for the interpretation of emotional intensities.

As a solution, in this paper we have proposed a new probability-model-based approach to determine IZOF and IZDy. It was demonstrated that the probabilistic method always provided more sensitive overall classification rates than the traditional method. Also, we suggested a relatively simple extension of the probabilistic approach to the measurement of multidimensional emotional intensities. However, we pointed out that the zone for each emotional intensity should be interpreted independently.

The issue of the relationships between the zones is an important one which deserves further investigation. For example, one might be interested in questioning whether a narrow IZDy in one emotional intensity dimension can be compensated by a wide IZOF in another such dimension to result in a high probability of overall optimal performance. This type of outcome cannot be solved unless the relationships between all the emotional intensity dimensions are taken into account. A multivariate approach should be applied to estimate a single probability as the total emotional effect, additive or interactive, for each of the IZOF and the IZDy by using a linear combination of the measures of emotional intensity. Another aspect that was overlooked in the past, which extends the IZOF concept, is the process by which the IZOF is reached. The positive and negative momentum states, which occur during the competition (Bar-Eli & Tenenbaum, 1989), should be incorporated into the model. These remain the challenges for further conceptualization of the IZOF.

References

Bar-Eli, M., & Tenenbaum, G. (1989). A theory of individual psychological crisis in competitive sport. *Applied Psychology: An International Review*, **38**, 107-120.

Freeman, G.L. (1940). The relationship between performance level and bodily activity level. *Journal of Experimental Psychology*, **26**, 602-608.

Hanin, Y.L. (1995). Individual zones of optimal functioning (IZOF) model: An idiographic approach to performance anxiety. In K. Henschen & W. Straub (Eds.), *Sport psychology: An analysis of athlete behavior* (pp. 103-119). Ithaca, NY: Mouvement.

Hanin, Y.L. (1997, Oct. 22-25). Emotions and athletic performance: What is beyond the zones? In *Fourth IOC World Congress on Sport Sciences. Training and care of athletes—Current concepts and technologies*. Monte Carlo: Congress Proceedings, Addendum, p. 27.

Hanin, Y.L. (Ed. 2000) *Emotions in sport.* Champaign, IL: Human Kinetics.

Turner, P.E., & Raglin, J.S. (1996). Variability in precompetition anxiety and performance in college track and field athletes. *Medicine and Science in Sports and Exercise*, **28**, 378-385.

Yerkes, R.M., & Dodson, J.D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology and Psychology*, **18**, 459-482.

Appendix

Based on Model 3, three logistic regression models are considered:

$$P_j^+ = \frac{1}{1 + \exp\left\{-[\beta_{0j} + \beta_1 \, (\mathrm{SAS})_i]\right\}}$$

where P_j^+ is the probability of obtaining jth or higher outcome values ($j = 1, 2, 3$, where 1 = MoP/B, 2 = OP, and 3 = MoP/A). In the equation, $(SAS)_i$ is the ith measure of *SAS* and the predicting variable. The same predicting variable is used for all three logistic curves. The outcome variables are recoded outcomes and are unique to each of the three logistic curves. For P_1^+, 0 is recoded into 0, and 1, 2, and 3 are recoded into 1. This way, the value 0 would indicate DyP, and 1 would indicate MoP/B or higher performance outcome. Similarly, 0 and 1 are recoded into 0, and 2 and 3 are recoded into 1 for P_2^+, and 0, 1, and 2 are recoded into 0, and 3 is recoded into 1 for P_3^+. Here, β_{0j} and β_1 are the intercept and slope for the jth logistic curve. The slope and intercepts are estimated for P_1^+, P_2^+, and P_3^+ by maximizing the likelihood function:

$$L(\beta_{0j}, \beta_1) = \prod_{j=1}^{3} \prod_{i=1}^{n} \left[\frac{\exp\left[\beta_{0j} + \beta_1 (SAS)_i\right]}{1 - \exp\left[\beta_{0j} + \beta_1 (SAS)_i\right]} \right]^{y_{ij}} \left[1 - \frac{\exp\left[\beta_{0j} + \beta_1 (SAS)_i\right]}{1 - \exp\left[\beta_{0j} + \beta_1 (SAS)_i\right]} \right]^{1-y_{ij}},$$

where y_{ij} is the ith-recoded outcome for jth logistic regression. However, there is no algebraic solution for β_{0j} and β_1, and they have to be obtained by a numerically iterative procedure such as Newton-Raphson method. Such a complicated estimation algorithm is readily available in some popular statistical package software. In the present study, the Ordinal Regression procedure in SPSS was used. A graphing tool (Excel spreadsheet) is available at http://garnet.acns.fsu.edu/~akamata/izof The tool requires the parameter estimates obtained by the Ordinal Regression procedure and produces plots similar to those presented in this paper.

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